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YOSHISUKE KISHIDA

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EDITORIAL

May Terrorism Cease and Peace Prevail

It maybe a little late on my part to extend New Year Greetings during the second month of the 21st century but nevertheless, "better late than sorry". hence, here's wishing AMA readers, advertisers and cooperating editors a much Happier and More Prosperous new Year!

That the year 2002 wa preceded by the disastrous terrorists' attack in the United States on September 11 was indeed a very sad day that will be remembered for a long time to come by the present generation. Equally sad was the offshoot of that attack on the fate of thousands of innocent

Afghanistans whose towns and rural areas were devastated as a side effect of the bombardment by the US and allies on the hideouts of the terrorists. To this day, the innocent civilians continue to suffer from hunger and the harsh winter weather.

Assuming that the interim Government succeeds soon in normalizing the peace and order situation in Afghanistan, the next step is to rebuild the war-torn areas that call for massive aid from the international aid-givers. Already an international conference was held recently in Tokyo to plan the provision of support to the rebuilding efforts.

In the meantime, urgent assistance from the advanced economically countries is badly needed to provide food, shelter, medicine and clothing to the suffering Afghanistans, particularly the aged, children and war orphans.

It is to be hoped that before long, terrorism shall cease and peace shall prevail so that the rehabilitation of lives and properties and the reconstruction of agriculture, services and industries can be initiated in Afghanistan.

It is in the agricultural reconstruction that AMA wishes to contribute via mechanization of agriculture to the attainment of peace and eradication of terrorism. Agricultural mechanization in certain land areas is surely a big step towards attaining peace and prosperity.

Yoshisuke Kishida
Chief Editor

Tokyo, Japan
February 2002

CONTENTS

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

Vol.33, No.1, Winter 2002

Performance Evaluation of Track System for Power Tiller

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Abstract

A track system was designed with canvas belt, chain, lugs, pulley, sprocket and tensioner assembly which was substituted for the tire in power tiller. A 8 mm thick, 8 ply fabric reinforced canvas endless belt running over a pulley sprocket system was used as track. The system was designed with a chain sprocket to keep the belt from slipping off the pulley and also to provide good tracking guide. The tractive performance of the track system was investigated and compared with that of the pneumatic tires used in power tiller. Evaluation was conducted in two types of soil with track and tire. A three fold increase in drawbar pull and drawbar horse power, 50 percent reduction in specific fuel consumption and 40 percent increase in tractive efficiency was obtained with the track systemcompared to the tire.

Introduction

Rubber crawter tracks are found on a variety of modern equipment from small earth moving machines to large tractors. In general, they are designed to provide efficient high draught drive on surfaces which would not bear the weight of or give adequate traction to agricultural vehicles. The best use of power tiller, during farming operations is when it is operating at high tractive efficiency. This tractive efficiency is affected by the interaction between ground drive system and ground support. It is determined by the configuration of ground drive system and strength of ground support at the track - soil contact area, hence, the reason for low tractive efficiency of the power tiller is due to a high percentage of wheel slip. One of the main reasons for the slow popularity of power tillers among Indian farmers is the low drawbar horse power availability. It is obvious that the characteristics of the present tractive elements impairs the tractive efficiency. In this paper, an attempt is made to improve the tractive performance of the power tiller by replacing the existing pneumatic tire with a track system.

Review of Literature

Osborne (1971) compared the tractive performance of a track layer with three-wheeled tractor and found that the average maximum tractive efficiency achieved by the track layer was 73% whereas those of the wheeled tractor varied from 56 to 68%. Taylor *et al.* (1975) made comparative studies on pneumatic tire, pneumatic track and steel track and reported that the steel track resulted in a better performance than the tire. Young (1977) concluded that a grouser spacing of approximately 200 mm was optimum. Evan and Gove (1986) reported that the tractive performance of rubber-tracked vehicle was better with higher pull, greater efficiency and lower rolling resistance than the wheeled tractor. Culshaw (1987) concluded that with track laying vehicles having steel tracks, the evidence was that the wider the spacing of grousers resulted in better the tractive performance. Culshaw and Dawson(1987) investigated the tractive performance of rubber track and tire on four different soil conditions and concluded that the tractive efficiency was always higher for the track than the tire. Culshaw (1988) reported that the vehicle on rubber crawler tracks could efficiently pull twice the load of a wheeled tractor of the same effective weight. Dwyer *et al.* (1989) reported that the co-efficient of traction at which maximum tractive efficiency was always much higher for track than for tire. Similarly, the slip at maximum tractive efficiency was always lower for the track.

Materials and Methods

The various components of the track system include a winged chain, sprocket, pulley and lugs. A 8-mm thick, 8-ply fabric reinforced canvas endless belt running over a pulley sprocket system is used as track because of its high stiffness and sturdiness against any ground undulations. The system was designed with a chain sprocket to keep the belt from slipping off the pulley and to provide good tracking guide, which ensures a positive drive (**Fig. 1**). A special type of chain commercially available with 19 mm pitch with upward projecting wings is attached with the track to pull the track and make it move uniformly. The chain and belt are fitted in a horizontal plane which passed through the centres of both belt and chain co-axially. Lug plates are attached over the track by riveting with an optimum spacing of 200 mm. Each track has 12 lugs. The lugs act like a knife edged grouser, running along the full track width at right angle to the direction of travel. They prevent direct contact of the canvas track with the ground. Padding are provided between the track and the lugs to prevent unnecessary contact between the lug and tip of the sprocket. The belt is tensioned by a screw thread tensioner which pulls the front idler axle towards a plate welded with a nut at the front side of the chassis. The two pneumatic wheels of the power tiller are replaced by tracking mechanism. The drive sprocket is fitted to axle of the power tiller and the drive is transmitted from rear axle to the front idler axle through the sprocket, chain, pulley and belt assembly. The idler pulley with sprocket is mounted at the bottom part of the power tiller in the front portion of the chassis. The track system is accommodated within the length of the chassis for better maneuverability, trafficability and for easy steering (**Fig. 2**). The centre to centre distance between the rear drive and front idler axles is 600 mm. Each wheel has a pair of pulley with a sprocket in between. The specification of the track is shown in **Table 1**.

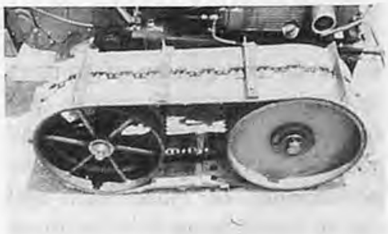

Fig. 1 Track system for power tiller.

Fig. 2 Power tiller fitted with rubber track.

The track system attachment to power tiller was evaluated for its performance in two soil conditions (black clay loam and red sandy) at 3/4 rated speed of the engine in the normal operating gear position (Low II) for the field operation. The performance was assessed in terms of drawbar pull (DBP), slip, drawbar horse power (DBHP) drawbar specific fuel consumption (DSFC) and tractive efficiency (TE) and was compared with tire. The drawbar pull, slip fuel and consumption of the power tiller were measured and the DBHP, DSFC and the tractive efficiency were computed and compared with the tire.

The slip of the power tiller was measured by monitoring the number of revolutions of the wheel over a distance of 30 meter under load and no load conditions. The revolutions made by the wheel was fed to a revolution counter through a speedometer cable. The revolution counter was mounted at appropriate height for easy observation. The slip was calculated by using the following formula.

$s = [(n_1 - n_0) / n_0] \times 100$

where,

s = wheel slip, per cent

n_1 = Number of revolutions of wheel under load for a distance of 30 m

Table 1. Specification of the Track System

Sl. No.	Particulars	Values
I. Track		
	Length × height × thickness, mm	257 × 230 × 8
	Chain pitch, mm	19.05
	Number of track	2
II. Lugs		
	Shape	L
	Length × height × thickness, mm	230 × 34 × 6
	Number of lugs	6
III. Pulley		
	Outer dia, mm	398.4
	Thickness, mm	6
	Number of sprockets	6
IV. Sprockets		
	Outer diameter, mm	417.4
	Root diameter, mm	394.3
	Number of teeth	67
V. Overall weight, including power tiller, kg		410
VI. Power of the power tiller, kW		7.46

n_0 = Number of revolution of wheel under no load for a distance of 30 m.

The forward speed of operation was calculated by observing the distance traveled and the time taken.

S = L / t

where,

S = Forward speed of operation, m/sec

L = Distance traveled, m

t = Time taken, sec

The Drawbar horse power (DBHP) for each run was calculated by using the following formula

$$DBHP = [(DBP)S / 75] \times 0.746$$

where,

DBHP = Drawbar horse power, kW

DBP = Drawbar pull, kg

S = Forward speed of operation, m/sec

The drawbar specific fuel consumption of power tiller was calculated by using the following expression.

$$DSFC = W_f / DBHP$$

where,

DSFC = Drawbar specific fuel consumption, lit / kW hr

W_f = Fuel consumed, lit/hr

The tractive efficiency (TE) of the power tiller was calculated by using the following expression.

$$TE = \frac{\text{Dranbar pull } (1 - \text{slip})}{\text{Dranbar pull} + \text{rolling resistance}} \times 100$$

Results and Discussion

The drawbar performance of the track system and tire is presented in **Fig. 3**. In the case of the tire, the pull Vs slip curve is almost a straight line with alittle curvature whereas for the track it gradually slopes upwards until 30 percent slip value and then steeply rises at right angle. The high reduction in slip for the track may be attributed to the fact that the higher conversion of axle torgue into tractive effort without energy loss in the soil-ground system interface. It is observed that in black clay loam soil that the maximum drawbar pull exerted by the track and tire is 2352 and 1630 N, respectively, whereas in the red sandy loam soil the values were 2357 and 1332 N. From the intreaction of DBHP Vs DBP, it is observed that the maximum DBHP of the track system is always higher than that of the tire in both the soils. The comprative performance of the track and tire for a standard slip of 15 percent is shown in **Table 2**. The drawbar pull exerted by the track is higher by almost three-fold when compared to the tire in both soils tested. Similarly, a three-fold increase in DBHP is also obtained by the track when compared to the tire.

The relationship between the DSFC and the drawbar pull for the track and tire is shown in **Fig. 4**. It is clear that the DSFC for the tire is lower than the track up to a critical point of the drawbar pull and after that, the DSFC is higher for the tire and it is very low for the track which is due to the fact that the percentage of frictional horse power to drive the track is higher as DBHP developed is less at lower levels of DBP. But the FHP required to drive the tire is lesser, the DSFC is lesser for lower pulls

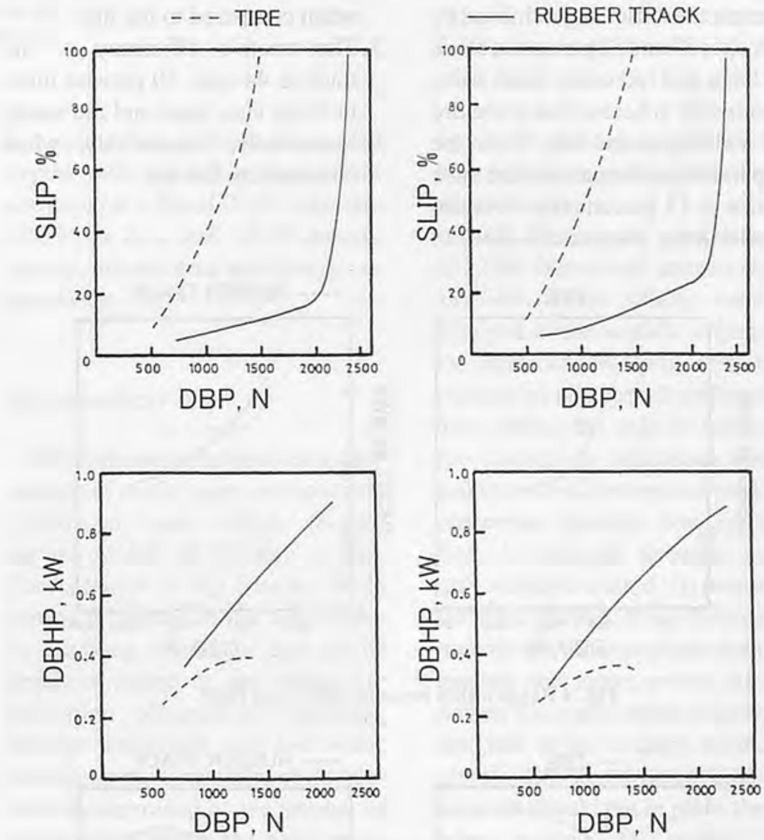

Fig. 3 Drawbar performance of rubber track and tire.

Table 2. Comparative Performance of Track and Tire at 15% Slip

S.No.	System	DBP (kg)	DBHP (HP)	DSFC(lit/kW h)	TE (%)
Black clay loam					
1.	Track	1810	0.83	1.74	55
2.	Tire	622	0.29	3.23	33
Red sandy loam					
1.	Track	1530	0.71	1.98	52
2.	Tire	530	0.24	3.71	31
Mean	Track	1670	0.77	1.86	55
	Tire	576	0.26	3.47	32

up to a critical point. After that the DBP developed is considerably higher resulting in more DBHP. But the frictional horse power for the track system remains almost the same and hence FHP drops significnatly when compared with the percent of DBHP developed. Consequently, the available horse power to do the useful work increases. From **Table 2** it is shown that the DSFC at 15 percent slip is almost 50 percent for the track as compared to the tire in both soils.

The relationship between the drawbar pull and the tractive efficiency of the track and the tire are is shown in **Fig. 5**. It is apparent that the maximum tractive efficiency achieved by the track is 57 and 52 percent in black clay loam and red sandy loam soils, respectively. Whereas that of the tire is 33 and 31 percent only. From the comparative performance of the track and tire at 15 percent slip it is observed that the tractive efficiency of the track is 44 and 40 percent more in blcak clay loam and red sandy loam soils respectively when compared to the tire.

Conclusions

Based on the results of thr investigation, the following conclusions are drawn:

1. Three-fold increase in DBP and DBHP is possible with the use of rubber track with power tiller when compared to the tire in both soils tested.
2. Fifty percent reduction in DSFC is also obtained by the track when compared to the tire.
3. The tractive efficiency of the track is 44 and 40 percent more in blcak clay loam and red sandy loam soils, respectively, when compared to the tire.

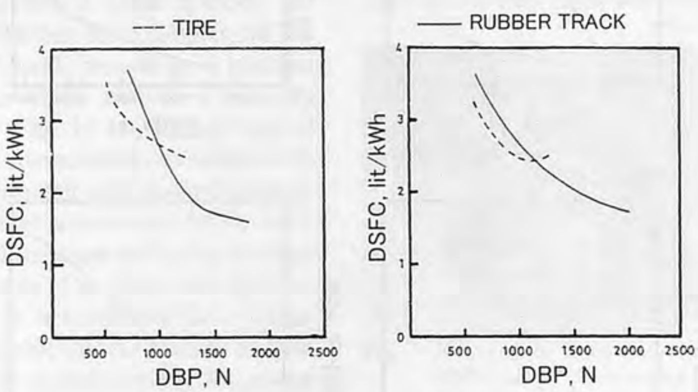

Fig. 4 Relationship beween DSFC and DBP.

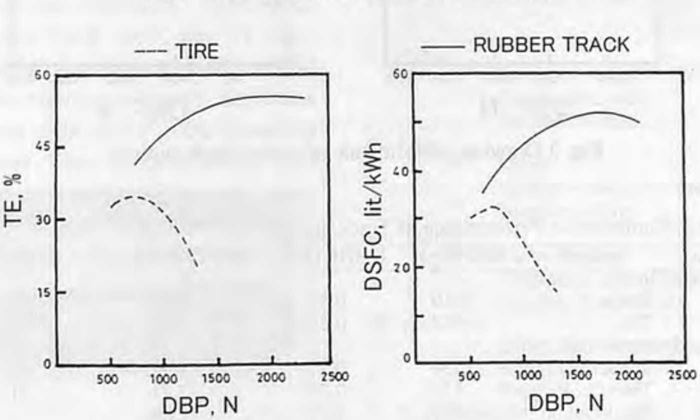

Fig. 5 Interaction between tractive efficiency and DBP.

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Performance Evaluation of Basin Lister Cum-seeder Attachment to Tractor-drawn Cultivator

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Abstract

In dryland farming it is important to have even a relatively small amount of water stored in the soil prior to sowing of crops. This can be achieved effectively by creating a multitude of small basins. A basin lister cum-seeder as an attachment to tractor drawn cultivator was developed for cotton to perform tilling, basin forming and sowing simultaneously. Keeping in consideration of day-by-day increase in tractor population, the unit was developed as a rear mounted attachment to four-wheel tractor of 35- 45 hp range and consists of common cultivator attached with a three bottom basin lister and mounted with a cup feed type seeder as attachments. The unit was evaluated for its performance in dryland for cotton crop cultivation. The amount of soil moisture observed was greater in the basin lister cum seeder treatment in all important stages and at all depths studied. The basin lister cum-seeder registered the highest seed cotton yield of 796 kg/ha which is 41.64 percent higher than control treatment. There was a positive relationship between the moisture content at various stages and depths with yield. The basin lister cum-seeder offered 31.41 percent, 96.30 per cent and 17.73 percent savings in cost, time and energy, respectively.

Introduction

Dry farming is the profitable production of useful crops, without irrigation on lands which receive annual rainfall of 700 mm or less. The potential of dry farming lands can be increased in the near future by adopting a suitable package of practices aimed at optimizing the utilization of available moisture through improved soil and water management. Generally, yield levels are determined by the amount of precipitation above the basic minimum required to enable the crops to achieve maturity. Agricultural machines play the role of exponents of progress in agricultural pursuits and welfare of the farming community. The first major thrust of agricultural mechanization is to reduce drudgery in field operations. Efficient use of costly inputs such as seeds, fertilizers and plant protection chemicals by proper and timely operation can be achieved by appropriate adoption of machinery.

With an annual production of 251,198 four-wheel tractors during 1997-98 (Anon., 1988), India has emerged as the world's largest tractor manufacturer. India now has a population of over 1.5 million tractors. Today, the sale of tractors in the country is increasing steadily and the use of tractors increases at a compound growth rate of more than 13 percent annually which may stabilize around 10 percent by the next decade. It is obvious that tractors are more popular and it has become the major source of farm power. The agricultural engineering program in the country should not merely aim at the supply of tractors, but should put in place the systems needed to ensure their sustainability. The system should cover areas such as a complete range of matching implements (Jain, 1995). For conserving soil moisture in dry land farming a basin lister / broad bed former cum-seeder as attachment to tractor drawn cultivator was developed.

Review of Literature

(Anon. 1987) developed a tractor-drawn basin lister attachment to cultivator and reported that the moisture level at different depths were more (2-5 percent) in plots treated with basin lister. Elmaeni and Elsahookie (1987) established the maize crop by sowing: (a) on ridges with basin listing; (b) in furrows; and (c) on the ridges and concluded that sowing on ridgers with basin listing out yielded other treatments producing grain yields of 7.37 and 11.9 t/ha from spring and autumn sowings, respectively. Nagarajan *et al.* (1988) evaluated basin lister, broad bed former and chisel plough in comparison with the conventional method for moisture conservation in dry farming and reported that the basin lister resulted in an increased crop yield of 11.0 percent as compared to conventional method of summer ploughing. Jones and Stewart (1990) reported that basin listing increases surface depression storage of precipitation, thereby potentially reducing storm runoff and increasing soil water storage availability to crops. Durairaj *et al.* (1992) reported that 2-4 percent more moisture was retained in the soil following basin listing compared to conventional ploughing. Channappa (1994) attempted to increase the crop yield through increasing opportunity time in the interterraced area and reported that the jowar grain yield was higher in listing system by 6.22 percent over the control.

Materials and Methods

The tractor-drawn basin lister cum-seeder was designed and developed to suit various cotton crop varieties in rainfed farming. The developed unit performs three operations simultaneously, viz., tilling, forming basins of size 0.30m width and 1.80m length and sowing cotton seeds in the centre of the ridge formed between two adjacent basins at the desired spacing and depth in a single pass. The sowing can be done in four rows at 0.45 m row spacing in one pass. The tilling mechanism consists of nine tynes. The basin listing mechanism consists of ground wheel, camshaft, cam, follower, follower arm, shank, lister and shovel (**Fig.1**). The seeder mechanism consists of cup feed type seed metering mechanism, spiked ground wheel, chain and sprocket drive for transmitting power from ground wheel to seed metering shaft and seed placement devices. A dog clutch is provided to engage and disengage the power to seed metering shaft. The basin lister portion can be easily detached from the cultivator and the unit can be converted into a broad bed former cum-seeder (**Fig.2**).

Tests were conducted in black cotton soil at the Tamil Nadu Agricultural University campus for evaluating the performance of the unit. The texture of the soil is sandy clay loam with clay - 24.20, silt - 18.80, fine sand - 14.23 and coarse sand - 42.77 percent. Cotton variety LRA 5166 was planted as a rainfed crop in an area of 0.55 ha in five equal plots. Each plot was considered as treatments. The following five treatments were selected for the study.

Fig. 1 Basin lister cum-seeder attachiment to tractor-drawn cultivator.

Fig. 2 Broad bed former cum-seeder attachiment to tractor-drawn cultivator.

T_1 - Tractor cultivator mounted Broad bed former cum seeder

T_2 - Tractor cultivator mounted basin lister cum seeder

T_3 - Tractor cultivator mounted ridger cum seeder

T_4 - Tractor drawn cultivator seeder

T_5 - Control (sowing behind country plough)

In each treatment, four replications were made. Before operating the first four implements (T_1 to T_4), the field was prepared by the following operations:

i. Disking once

ii. Ploughing with cultivator once

For control treatment (T_5) the field was prepared by the following operations:

i. Disking once

ii. Ploughing with cultivator twice

The time required to cover the area, the time lost for turning, average travel speed, actual quantity of seeds used were measured during the operation.

Soil samples were taken in four replications at 150, 300 and 450 mm depth of all treatments in field periodically during the crop period. The soil samples were weighed and then oven dried at 105 degree centigrade for 8 hours. The weight of the dried samples were recorded. The soil moisture content in dry basis (percent) was calculated. The seed cotton obtained from the net plot area in each picking were pooled, weighed and expressed as crop yield in kg / ha for the individual treatments.

Results and Discussion

Moisture Depletion Pattern

The soil moisture status at 150 mm, 300 mm and 450 mm depths at different stages of crop growth is shown in **Figs. 3a** to **3c**. The rainfall received during the crop growth period is superimposed in all the soil moisture status curves. It is observed that at different stages of the crop growth, namely; monopodial stage, sympodial stage, flowering stage, boll formation stage and boll bursting stage, the soil moisture recorded was greater in the basin lister cum-seeder treatment (T_2) when compared to other treatments at 150, 300 at 450 mm depths of soil. To confirm the above results the soil moisture data obtained at 150, 300 and 450 mm depths in the various in-situ moisture conservation treatments selected for the study was analysed by performing factorial randomized block design (FRBD).

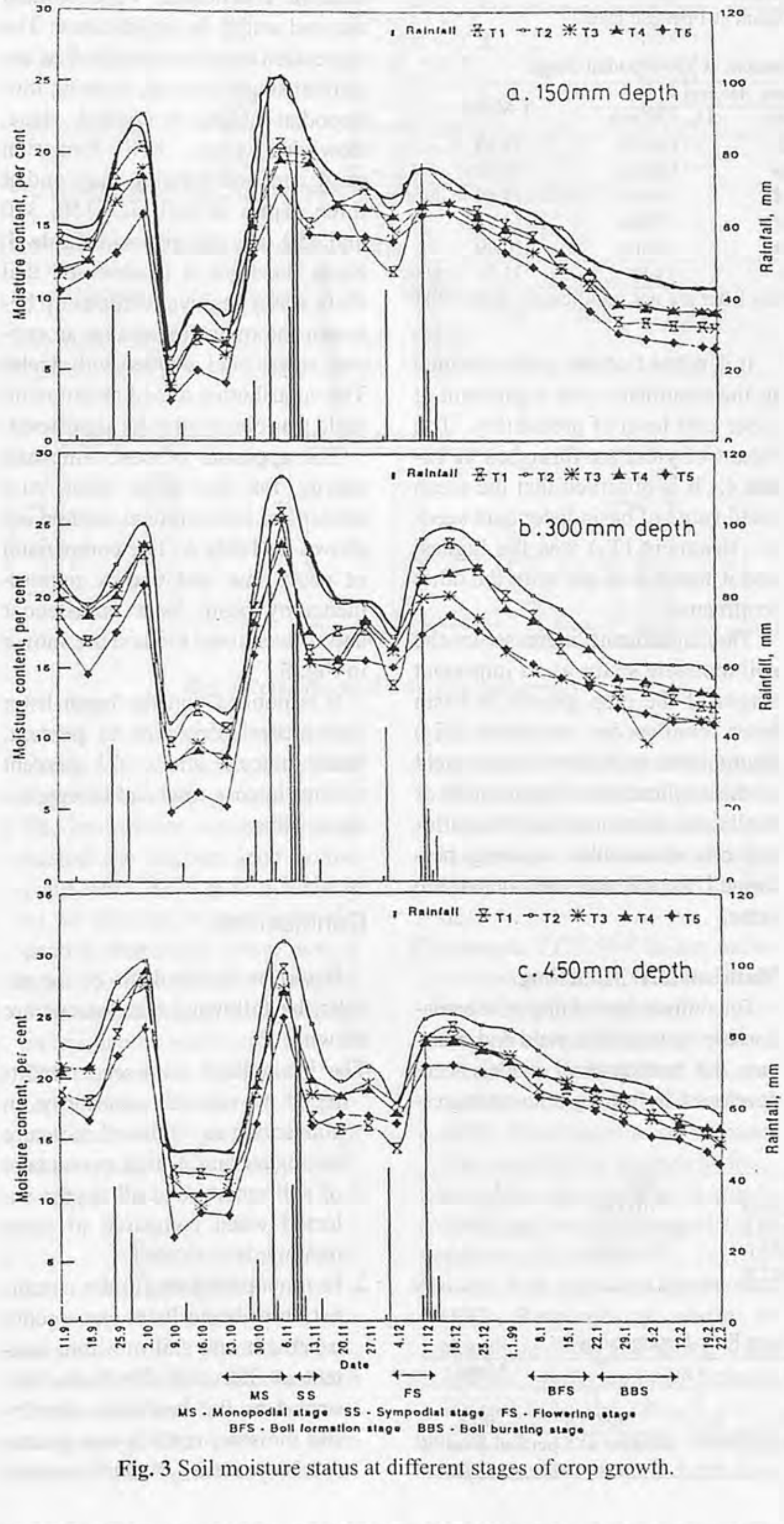

Fig. 3 Soil moisture status at different stages of crop growth.

Monopodial stage

The results of the ANOVA for the soil moisture content measured during the monopodial stage is shown in **Table 1**. It is observed that the F value was significant at 1 percent level of probability for all the treatments and also for all the treatment combinations. This indicated the importance of each combinations and hence each combination had to be compared separately.

To arrive at the best combination (treatment and depth) mean values of the moisture content were arranged in the descending order. On the topmost, the mean value which was not at par with any one was considered as the best combination. The means for moisture content is shown in **Table 2**.

Thus the combination of basin lister cum-seeder treatment (T_2) and soil moisture content at 450 mm depth (D_3) was observed as the best with a maximum moisture content of 18.5 percent. It was also observed that the basin lister cum-seeder treatment was superior in soil moisture storage by registering high percentage of soil moisture at all depths when compared to other treatments.

Sympodial Stage, Flowering Stage, Boll Formation Stage and Boll Bursting Stage

From the results of ANOVA it is observed that a similar trend to that of the monopodial stage is shown at all other important stages of the crop growth. Thus the basin lister proved its superiority in conserving higher soil moisture at all important stages of the crop growth over all the others in-situ soil moisture conservation treatments selected for the study.

Table 1. Analysis of Variance for Soil Moisture Content at Monopodial Stage

Source	df	SS	MS	F
Replications	3	4.1029	1.3676	3.90*
Treatments	14	490.6275	35.0448	99.88**
T	4	164.4627	41.1156	117.19**
D	2	295.0094	147.5047	420.41**
T × D	8	31.1553	3.8944	11.10**
Error	42	14.7360	0.3508	
Total	59	509.4664		

* = Significant at 5 percent level. ** = Significant at 1 percent level.

Table 2. Table of Means for Soil Moisture Content at Monopodial Stage

Treatments	Soil moisture content, per cent			T-Mean
	D_1, 150 mm	D_2, 300 mm	D_3, 450 mm	
T_1	10.36b	15.02b	15.33b	13.57
T_2	11.78a	16.30a	18.50a	15.52
T_3	10.73b	12.51d	15.44b	12.89
T_4	10.94ab	13.51c	17.80a	14.08
T_5	8.56c	10.55e	12.36c	10.49
D-Mean	10.47	13.58	15.88	13.31

Note: In a column, means followed by a common letter are not significantly different at the 5 percent level by DMRT.

Crop Yield

The seed cotton yield obtained in all the five treatments is shown in **Fig. 4**. It is observed that the basin lister cum-seeder treatment recorded the highest yield of 796 kg/ha whereas the control treatment registered the lowest yield of 562 kg/ha. To confirm the validity of the above result, statistical analysis was done on the yield data of the treatments. The ANOVA for yield is shown in **Table 3**.

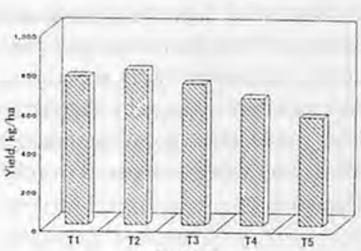

Fig. 4 Seed cotton yield.

It is noted that the yield obtained in the treatments was significant at 1 per cent level of probability. The means of yield are furnished in **Table 4**. It is observed that the mean yield value of basin lister cum seeder treatment (T_2) was the highest and it was not on par with the other treatments.

The significant increase in the soil moisture status at all important stages of the crop growth in basin lister cum-seeder treatment (T_2) might have influenced more yield as the application of inputs such as fertilizers, pesticides and the farming operations like weeding performed in all the treatments are same.

Mathematical Modelling

To confirm the validity of the relationship between the yield and moisture, the mathematical models were developed by multiple linear regression analysis. To establish the relationship between the yield and the soil moisture status at different depths of soil and at important stages of crop growth, mathematical models were developed and the correlation coefficients were worked out and tested for significance. The regression equations for the five important stages of crop, namely; monopodial stage, sympodial stage, flowering stage, boll formation stage and Boll bursting stage and at three depths of soil viz., 150, 300 and 450 mm are given in **Table 5**. From the table it is observed that there was a positive relationship between the moisture content at various stages and depths with yield. The contribution of soil moisture on yield was observed to be significant.

The appraisal of cost, time and energy for the basin lister cum seeder and conventional method are shown in **Table 6**. The comparison of cost, time and energy requirements by basin lister cum-seeder and conventional method are shown in **Fig. 5**.

It is noticed that the basin lister cum-seeder offered 31.41 percent, 96.30 percent and 17.73 percent savings in cost, time and energy, respectively.

Conclusions

Based on the analysis of the results the following conclusions are drawn:

The basin lister cum-seeder treatment proved its superiority in conserving in - situ soil moisture by registering a high percentage of soil moisture at all depths selected when compared to other treatments evaluated.

2. In monopodial stage, the combination of basin lister cum-seeder treatment and soil moisture content at 300 mm depth was observed as the best since the insitu moisture content was greater (16.30 percent). A similar trend

Table 3. Analysis of Variance for Yield

Source	df	SS	MS	F
Replications	3	210.0	70.0000	< 1
Treatments	4	138860.8	34715.2000	488.95**
Error	12	852.0	71.0000	
Total	19	139922.8		

** =Significant at 1 percent level.

Table 4. Table of Means for Yield (Average over Four Replications)

Itme	T_1	T_2	T_3	T_4	T_5	Mean
Rank	4	5	3	2	1	
Yield, kg/ha	762.0 d	796.0 e	726.0 c	656.0	562.0 a	700.4

(Means followed by a common letter are not significantly different at 5 percent level by DMRT).

Table 5. Regression Equations for All Stages and Depths

Stage	Depth,mm	Equation	R^2 value
I Monopodial	150	Y = 97 + 58 X	0.63**
	300	Y = 238 + 34 X	0.75**
	450	Y = 454 + 15 X	0.23*
II Sympodial	150	Y = 194 + 26 X	0.57**
	300	Y = 108 + 28 X	0.62**
	450	Y = 59 + 27 X	0.61**
III Flowering	150	Y = -179 + 55 X	0.44**
	300	Y = -62 + 42 X	0.54**
	450	Y = -862 + 78 X	0.78**
IV Boll formation	150	Y = 65 + 50 X	0.53**
	300	Y = 259 + 27 X	0.34**
	450	Y = -252 + 50 X	0.43**
V Boll bursting	150	Y = 320 + 42 X	0.52**
	300	Y = 137 + 43 X	0.45**
	450	Y = -224 + 54 X	0.54**

* = Significant at 5 percent level. ** = Significant at 1 percent level.

Table 6. Appraisal of Cost, Time and Energy

Method	Cost, Rs./ha	Time, h/ha	Energy, MJ/ha	Percent savings		
				Cost	Time	Energy
Conventional method	3532.00	237.98	1850.44	-	-	-
Basin lister cum-seeder	2422.75	8.81	1522.37	31.41	99.11	17.73

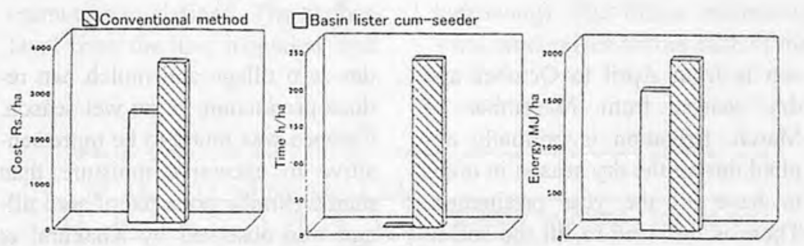

Fig. 5 Comparison of cost, time and energy.

to that of monopodial stage was shown at all other important stages of the crop growth.

3. The basin lister cum-seeder registered the highest seed cotton yield of 796 kg/ha which is 41.64 percent higher than the control treatment. There was a positive relationship between the moisture content at various stages and depths with yield.
4. The basin lister cum-seeder offered 31.41 percent, 96.30 percent and 17.73 percent savings in cost, time and energy, respectively.

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Effect of Water Application Rates And Tillage on the Growth and Yield of Cowpea


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Abstract

Seed and dry matter yields and growth of cowpea (Vigna unguiculata L. Walp.) were studied under two tillage systems and varied water rates on the field using a line source sprinkler system. The two tillage systems are minimum and conventional. Yields increased with increasing water application. Minimum tillage produced higher shoot and grain yield but lower root than conventional tillage. There was no significant difference between the two tillage systems in the number of pods per plant. However, minimum tillage produced longer pods. There was no significant interaction between tillage and water rates.

Introduction

Cowpea is currently using under irrigation system in Nigeria to increase production since it is the main source of protein in the local diet and for the enrichment of soils that had been planted to other crops in previous years. Nigeria has two main seasons (wet and dry). In southwestern Nigeria, the wet season is from April to October and dry season from November to March. Irrigation is normally applied during the dry season in order to have all the year production. There is the need to till the soil at least once before planting because it would have hardened due to excessive evaporation. Lal (1973) and Nangju (1979) showed that maize and cowpea did not respond to ridges and furrows. A study by Osuji (1984) on the water storage, water use and maize yield for different tillage systems in Nigeria showed that zero tillage has potential for higher yields than the other systems. He however suggested that the difference in soil water content between the tillage systems need to be more closely examined. Simpson and Gumbs (1985 ; 1992) and Lindsay et al. (1983) have studied the production of cowpea and maize on clay soils in Trinidad and Guyana with and without tillage and mulch and with different systems of field layout to facilitate drainage. These studies show that zero tillage has potential for year round crop production, especially when the rainfall regime is not high and that the higher soil moisture under zero tillage and mulch can reduce production in the wet season. Cowpea was found to be more sensitive to excessive moisture than maize. Similar potential of zero tillage was observed by Khakural et al.(1992). However, Gumbs and Lindsay (1993) found no difference between no till and tilled soil under irrigation conditions.

Hanks *et al.* (1976), used a line source sprinkler technique to produce a water application pattern which is uniform along the length of the plot and continuously variable across the plot. They suggested that fertility or any other variable could be applied at right angles to the water variable to generate a crop production function data. Fapohunda and Adekalu (1993) used this continuous variable design to generate response surfaces for cowpea with two variables - water and fertilizer. They obtained similar result as those derived from a randomized complete block, split plot design but with a more compact land area.

This study was, therefore, undertaken to assess the growth and yield response of cowpea to tillage and irrigation water deficit using line source sprinkler system.

Materials and Methods

Field studies were conducted at the Teaching and Research Farm of the Obafemi Awolowo University, Ile-Ife, Nigeria on a silty loam soil classified as an Alfisol. The line source sprinkler system (Hanks *et al.*, 1976) was set up in a North - South direction at the site (**Fig. 1**). The approximate plot dimensions were 30 m (E- W) × 100m (N- S), including border areas and tractor turning area running between adjacent sub-plots. Nine different irrigation levels perpendicular to each side of the line source in 1.5 m increment was defined. The farthest level from the line, irrigation level IL9 (either east or west) received essentially no irrigation water (after initial one for crop establishment) while IL1 just adjacent to the line, received a maximum water supply. The line source irrigation system used impact sprinklers, Rainbird 30, 4.76, by 2.32 mm - 7° slotted nozzles spaced at 6m along the lateral. Pressure at the inlet averaged 300kPa and the average discharge per sprinkler was 0.5L/s with a wetted diameter of 30m.

Cowpea, variety IT84E-124, was planted at a spacing of 30cm on rows 75cm apart. The tillage treatment consisted of two levels of minimum tillage (disc ploughing alone) and conventional tillage (double disc ploughing followed by harrowing). The tillage treatments were randomised within each of the four replications of the experiments. Weeds and insect pests were controlled as and when necessary using standard procedures. Two uniform irrigations one at planting, and the other, three days after planting (DAP) were done to encourage seedling establishment and uniform crop vigour. Line source irrigation was then started 7 days after sowing to initiate water variable treatments.

At each irrigation level, evapotranspiration was estimated from the following water balance equation:

$$ET = R_e + I + SWD - D \text{ ....(1)}$$

where ET is evapotranspiration in mm, R_e is effective rainfall in mm, I is irrigation in mm, SWD denotes soil water depletion in mm and D denotes drainage in mm.

Rainfall was measured with a rain gauge and cross checked with readings obtained at a nearby weather station on the farm with effective rainfall taken as 70% of the total rainfall depth (Lal, 1984). Irrigation depths were measured at each irrigation with wide mouth catch cans placed at the mid-point of each water level (IL9 west through IL9 east) in two of the replications. Irrigations were scheduled at weekly interval of sufficient duration to meet ET needs of the crop at a distance of 0.75m (IL1) from the line. The depth of irrigation needed was estimated from calculated ET using the modified Penman equation (Wright, 1982). This amount of irrigation maintained the soil water content at essentially a no depletion level in the highest water treatment (IL1) as determined from neutron probe readings. Soil water content was monitored at 14-days interval with one-half of the access tubes being read one week and the others the following week. Selected IL1 tubes were read weekly and used in the irrigation scheduling check.

Neutron probe access tubes was established at the center of alternate irrigation levels (i.e. IL1W, IL3W, IL5W, IL7W, ILW9, IL2E, IL4E,

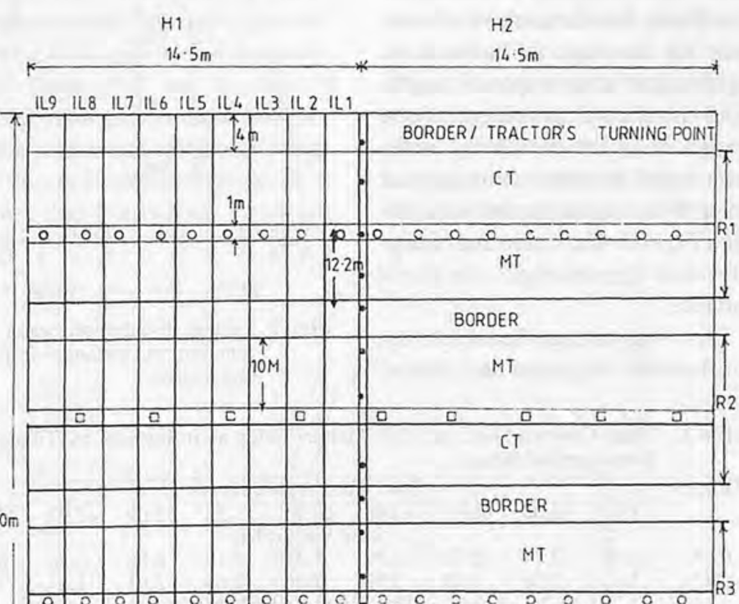

Fig. 1 General layout for cowpea irrigation and tillage treatments.

IL6E, IL8E) in one replication of each tillage treatment. The access tubes, placed to a depth of 1.8m, were standard 51mm diameter aluminium irrigation pipes installed in hand-augered holes. The probe of the neutron was lowered into these holes to take readings at the depths indicated in **Table 1**. The major contribution to ET in equation 1 were irrigation and rainfall which constituted the total applied water. Prior to maturity, samples from irrigation levels 1, 5, 7 and 9 were taken at 7, 15, 30, 45 DAP to determine the dry matter of shoots and roots. One-eighth of the irrigation sub-plot was used for each sampling. It was not possible to monitor the plant height because the variety is the creeping type. The penetration resistances of the soils at these irrigation levels were determined using a standard cone penetrometer.

At maturity, the remaining portion of each of the irrigation sub-plots were divided. Half of the area was harvested for seeds and the other half for dry matter yields. Dry matter samples were kept in an oven maintained at a temperature of 50°C and drying continued until a constant weight was achieved. The field weights of seeds were corrected to 12% moisture content.

The design of the system is similar to that of the split-block system in which the tillage treatments constitute the main plots and irrigation levels the sub-plots. Although the tillage treatments were randomized within the replicates, irrigation level treatments were not because of the systematic and continuous nature of application. It was, therefore, not possible to find a valid value of F for the variance analysis of the irrigation effect or its interaction with tillage. However, since irrigation effect is usually considerable, this is not considered critical. Each half of the original replications were treated as replicates, so that the position effect was included within the block effect.

Table 1. Reading Depths Soil Water Content Layers*

Reading depth (cm)	Represented soil water content in layer (cm)
10	0-20
30	20-40
50	40-60
70	60-80
90	80-100
110	100-120
130	120-140
150	140-160
170	160-180

*Use of neutron probe.

Results and Discussion

There was a general decrease in total applied water with distance away from the line source and the relation was nearly linear. **Table 2** contains the means and standard errors of cowpea seed and dry matter yields. The data show the main effects of tillage, total applied water, and tillage by applied water interaction. **Table 3** is the analysis of variance for the data in **Table 2**. A highly significant response, at 1% level is shown to tillage. Even though no valid probability statement could be made about applied water(W) or its interaction with tillage (T), both the water and tillage effects are large enough to be of importance.

There was no significant interaction between irrigation and tillage. Substantial amounts of cowpea (both seed and dry matter) were produced even with low inputs of water. Cowpea, being a leguminous crop, fixes nitrogen in its roots and it has been shown to be a drought-tolerant crop by some workers (Turk et al., 1980; Ziska and Hąll, 1983). However, there was a gradual decrease in yield with decreasing water application. This is in contrast to the observation

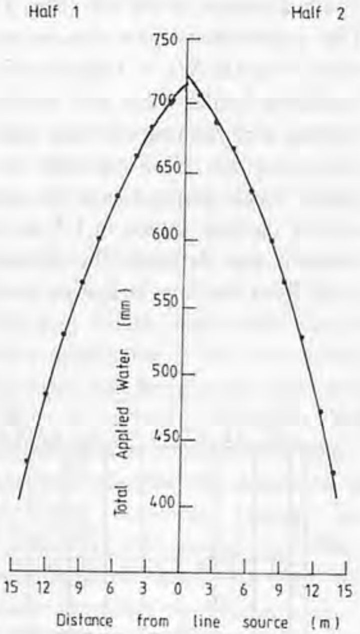

Fig. 2 Lateral distribution water as a function of distance from the line source.

Table 2. Mean Cowpea Seed and Dry Matter Yields as Influenced by Tillage and Total Applied Water

Tillage	Total Water Applied (cm)								
	71.99	68.06	66.09	63.90	60.10	57.59	52.09	47.97	42.18
	Seed Yield (t/ha)								
CT*	3.09	3.14	2.75	1.82	1.41	1.16	0.86	0.76	0.46
MT*	5.63	3.16	3.78	3.52	3.36	2.64	2.03	1.57	1.08
	Dry matter Yield (t/ha)								
CT	12.33	10.86	8.15	6.57	5.58	4.32	3.34	2.60	2.13
MT	17.36	13.80	11.07	9.66	8.92	8.09	7.46	6.58	4.91

* CT = Conventional tillage.
* MT = Minimum tillage.

Table 3. Analysis of Variance for Cowpea Seed and Dry Matter Yields

Source	Degrees of freedom	Seed Yield		Dry matter	
		Mean	Observed F	Mean	Observed F
Replication (R)	5	1.22	-	5.42	-
Tillage (T)	1	29	16.37**	237	8.66**
Error a (T × R)	5	0.84	-	3.52	-
Applied Water (W)	8	11	-	112	4.07*
Error b (W × R)	40	6.2	6.03*	10.82	-
T × W	8	8	-	10	0.05 NS
Error c (T × W × R)	40	-	0.58 NS	-	

** Significant at 1%. * Significant at 5%. NS not significant.

by Gumbs and Lindsay (1993) that different irrigation intervals had no significance difference on the yield of cowpea, probably because there was stress throughout the growing season in this study. This study also shows that spreading the stress throughout the entire season will produce better yields than when the stress is imposed on a particular stage. Substantial reductions have been observed when small stress is imposed only on particular stages (Turk et al., 1980; Hiler et al., 1971; Summerfield *et al.*, 1976)

Minimum tillage produced greater yields than the conventional tillage for all the levels of water application. However, the difference increases with decreasing level of water application. Thus, the difference may become more significant when the result is expressed as yield-water use index.The result corroborates the findings of earlier researchers (Osuji;1984, and Lindsay et al.,1983) that greater yields were obtained at zero and minimum tillage than the conventional tillage. It is known that continuous minimum tillage can lead to the establishment of weed species which are difficult to eradicate. Therefore, weed control would have to be considered in the development of the cropping system which includes long duration minimum tillage cultivation. Also, the higher penetration resistances for minimum tillage can give continuous high soil water potential throughout the growing season during period of high rainfall and cowpea had been shown to be sensitive to excessive moisture by Gumbs and Lindsay (1993).

The differences in yield between the tillage treatments resulted from differences in the pod length per plant as there was no significant difference between the two tillage treatments in terms of number of pods per plant (**Table 3**).

There was no significant differences between the shoot growth under the two tillage system at the initial stage of development (<30DAP) for irrigation levels (IL) 5 and 9. The shoot growth under irrigation level one was consistently higher than those under irrigation levels five and nine from 15 DAP. Between emergence and 15 DAP there was no significant difference between the tillage and irrigation treatments probably because the initial uniform application of water did not allow the effect of tillage and irrigation treatments to show at this time.

Minimum tillage (MT) gave higher shoot yields than conventional tillage (CT) for all the irrigation levels between 30 days after planting (DAP) and maturity. CT gave higher root yields than MT for all irrigation levels. Like the shoot development, there was no significant difference in the root development below 30 DAP between the two tillage systems for irrigation levels five and nine. Between 30 DAP and maturity, CT gave higher root yields than MT for all irrigation levels. The higher root yields for CT might be due to lower resistances of the soil under the system throughout the growing season (**Table 4**). There was no appreciable root growth after 45 DAP, thus values at 60 DAP are not shown. This suggests that root growth terminated at 45 DAP. Irrigation level one pro-

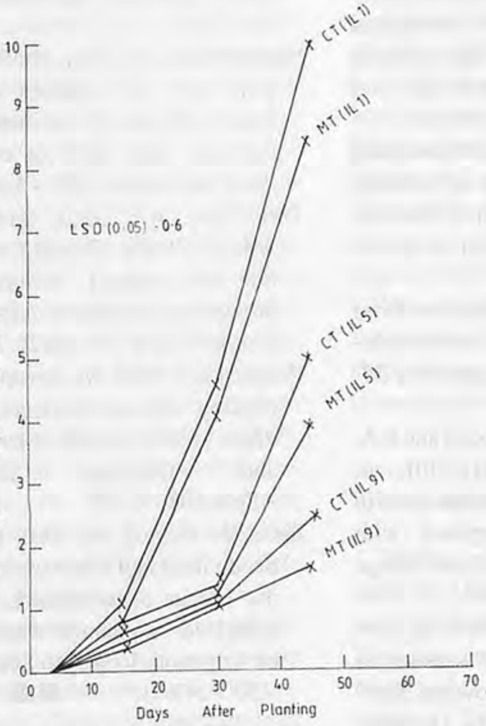

Fig. 3 Effect f tillage and water stress on root growth.

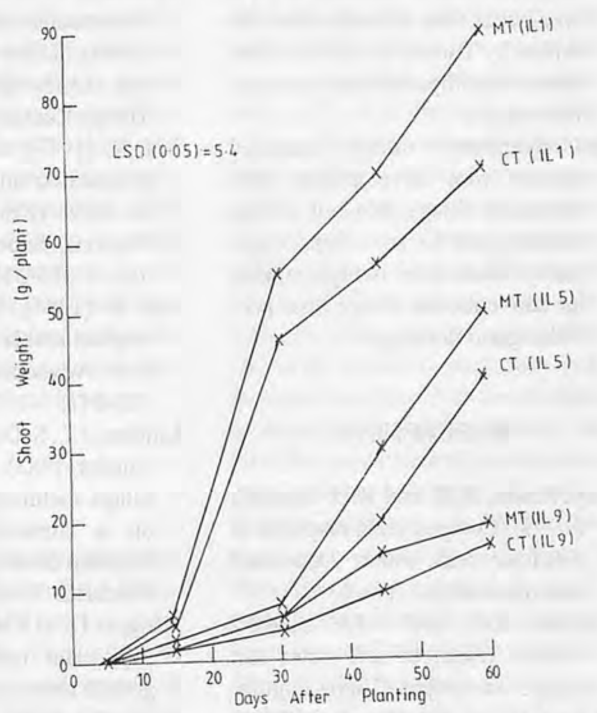

Fig. 4 Effect f tillage system and water stress on shoot growth.

duced greater shoot and root for each tillage system than IL5 and IL9. Below 30 DAP there was marginal increase in crop development per unit water added. This falls within the vegetative stage that suggests that cowpea can withstand drought at this stage as observed by some previous researchers (Hiler et al., 1971; Turk et al., 1980). The differences in the shoot yields for the different irrigation levels are more pronounced from 45 DAP to maturity. This probably confirms that cowpea is sensitive to drought during the floral initiation to fruit set stages.

Table 4. Penetration Resistance of Soil as Influenced by Tillage and Irrigation Level

Treatment	Irrigation level	DAP	Depth 10cm Before irrigation	10cm After irrigation	20cm Before irrigation	20cm After irrigation
			Penetration Resistance (N)			
CT	1	15	1.70*	1.54	4.52	2.54
		30	1.16	0.44	2.94	1.62
		45	4.84	2.34	9.92	5.45
	9	15	1.46	0.74	4.82	1.14
		30	1.00	0.47	4.30	1.59
		45	6.12	3.59	10.54	8.60
MT	1	15	2.27	1.70	7.45	2.36
		30	1.43	0.60	5.02	1.75
		45	6.22	4.54	10.40	7.34
	9	15	3.73	1.51	8.41	3.50
		30	1.70	0.55	6.73	2.88
		45	7.15	4.88	10.63	5.96

*Values are means of 6 replicates. DAP = Days after planting.
CT = Conventional tillage. MT = Minimum tillage.

Conclusions

The following conclusions can be drawn from this study:

1. Minimum tillage produced greater yields (seed and dry matter) than conventional tillage with the difference becoming more pronounced with decreasing water application.
2. There was a gradual decrease in yield with decreasing water application but the decrease in yield was better than the reductiion obtained by Turk *et al.* (1980) when stress was imposed only at one or two stages.
3. Conventional tillage produced greater root development than minimum tillage, hence it will be better suited for root crops, especially when there is high rainfall as conventional tillage also provides good drainage.

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Field evaluation of an Indigenous Farmer-managed, Furrow-irrigated System in the Western Highlands of Cameroon

by

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Abstract

Research on farmer-managed, small-scale irrigation in Africa, South of the Sahara, has generally been neglected in favour of large-scale systems even though most farmers use small-scale systems. As a result very little is known on how farmer-managed systems are managed or how well they function- a pre requisite for any successful interventions to ameliorate such systems. Paradoxically, large-scale systems in the region have frequently proved to be unsustainable. The aim of this study was, therefore, to evaluate the performance of the physical sub-system of an indigenous large-ridge, farmer-managed, furrow irrigated system so as to understand its operation and to suggest ways by which the productivity of the system can be enhanced.

Performance parameters were determined for the field application sub-system and compared with target values. The spatial distribution of water along furrows with different slopes was also determined and the effect of slope on performance parameters and yield studied. Contrary to conventional engineering wisdom, it was found that the low technology, high labour large-ridge system had an excellent average application efficiency of 63 percent on a silty loam soil. The slopes of the furrows were found to greatly affect the distribution of water along the furrow and consequently the yield. Yields were found to be about 40% higher on a field with an average slope of 0.83% compared to one with a slope of 2.6%. For improved performance, it is recommended that the slope along the closed-ended furrows should be preferably zero.

Introduction

The history of irrigation development in Africa, South of the Sahara, is far from being a success story. This has especially been so with large-scale, state owned irrigation systems. Carter (1989) identified numerous reasons for these failures. One manifestation of the lack of success is that, there is a very large discrepancy gap between the actual output of the systems and the expected output.

FAO (1986) estimated that in 1982 about 55% of the irrigated lands in Cameroon were under the large-scale, formal irrigation sector while 45% was devoted to small-scale or farmer-managed systems. Other studies indicate that most research in Cameroon until recently had been carried out mainly on large-scale irrigation systems (Moris and Thom, 1985). As a result, very little is known of small-scale systems that are more common with the local farmers. However, with the collapse of some large-scale systems in the 90's, the importance of farmer-managed systems has been increasing. There is, therefore, a realisation that more research and development efforts should be directed to small-scale systems because they offer better chances of sustainable irrigation development in Cameroon. The importance of research in small-scale irrigation systems has also been advocated by many researchers (Martin et al., 1986; Carter, 1989; Brown, 1999).

The Western Highlands agro-ecological zone of Cameroon is situated between latitudes 5° and 7° North of the equator and between longitudes 8° and 12° East. The growing season is between 240 and 270 days per annum. This region has one of the highest population densities in Cameroon (Consult, 1995), and is also one of the most productive agricultural areas of the country.

To increase the agricultural production and hence farm revenue, irrigation is practised in the dry season that runs from mid-November to mid-March. The irrigation systems are typically farmer-managed and are used for the cultivation of vegetables like carrots, leeks, cabbages, celery, tomatoes and green beans. The crops are mainly surface irrigated, while some are irrigated with gravity sprinkler systems where the topography permits. To diversify the crop production system, the cultivation of green peas has been recently introduced. The peas are cultivated in the dry season for export to European markets. The large-ridge system has been identified to be the main irrigation method used by farmers for irrigating farms of up to 4 ha of green peas (Fonteh et al., 1998).

Conventional engineering wisdom assumes that farmer-managed systems are inefficient in the capture, conveyance and distribution of water because of the rudimentary technologies used (Martin et al., 1986). Many interventions in such systems using classical approaches with the aim of improving the performance have been unsuccessful. This has been partly due to the fact that such interventions did not fit into the socio-economic and cultural context of the environment (Minae and Ubels, 1993). Before specific interventions can be considered, we need to first understand how farmers manage their system and secondly, how well the system is managed. It is only after this that intelligent decisions can be made on improvements required if any.

The aim of this study was to evaluate the performance of the water use sub-system of an indigenous large-ridge, farmer-managed furrow irrigated system so as to understand its operation and to suggest ways by which the productivity of the system can be enhanced. The specific objectives were to: (a) determine the performance efficiency parameters of the sub- system; (b) study the effect of slope on the performance parameters and the yield and; (c) suggest suitable ways of improving the performance.

Materials and Methods

The study was carried out on two adjacent farms in Mbouda, a town in the West Province of Cameroon from November 1997 to April 1998. A plot size of about 400 m^2 was chosen on each farm for the experiment. The downhill slope varied from 10 – 15% on the site. These slopes are common in the area where farmers practice irrigated agriculture on slopes of up to 30%.

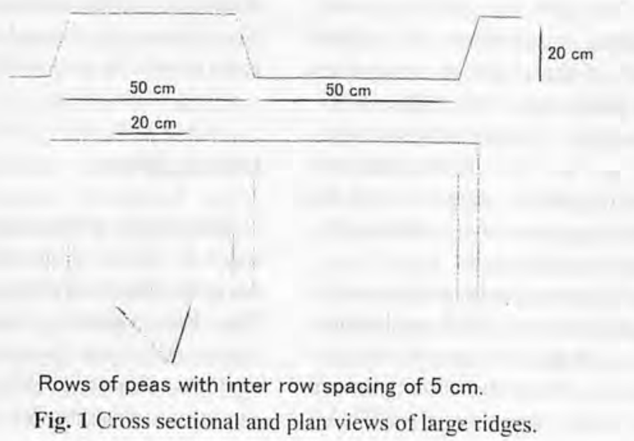
The widths of the furrows and the ridges at the base were about 50 cm as shown on **Fig. 1**. The large ridges and furrows were adopted by the farmers because they provide easy passage for carrying out cultural operations like staking, fertilizer applications, and harvesting. Water from the head ditch is diverted into a single large furrow with the aid of potable metallic check structures placed immediately downstream from the furrow inlet in the head ditch. As the water advances down the closed-ended furrow, it is lifted with spades from the furrows onto the surface of the large ridges. This is to facilitate infiltration into the centre of the large ridges. The lengths of the furrows are about 20 m and required 2 persons to irrigate each furrow.

To determine the efficiency of water distribution, the following performance parameters as defined by Walker and Skogerboe (1987) were calculated: application efficiency (E_a); tailwater ratio (TWR); deep percolation ratio (DPR); and requirement efficiency (E_r). Another parameter used in surface irrigation to quantify the performance is the distribution uniformity, (DU). Merriam and Keller (1978) define this parameter as **Equation 1**:

$$DU = \frac{\text{Volume of water stored in the least watered quarter of the field}}{\text{Volume of water applied to the field}} \times 100$$

Equation 1

In a complete irrigation, where the soil water deficit is exactly met at the end of the field, the require-



Rows of peas with inter row spacing of 5 cm.

Fig. 1 Cross sectional and plan views of large ridges.

ment efficiency should be 100% and the uniformity of application should be as high as possible. The tail water ratio and the deep percolation ratio are losses that have to be minimized. Once the parameters are known, they can then be compared with target acceptable values. Walker (1980) gives the target values of the application efficiency and the distribution uniformity for furrows as 40-70% and 80-90%, respectively.

The following variables were measured and used to determine the parameters:

* The duration of irrigation.
* The inflow rate into each plot.
* The outflow volume from each plot was measured using collectors that were installed for erosion studies. The outflow was only recorded in cases of water over-topping the closed-ended furrows.
* The required applied depth of irrigation was determined as the difference between the field capacity of the soil and the actual moisture content on the day of the irrigation. The field capacity was calculated using the approximation suggested by Bradley and Crout (1994) as 50% of the saturated moisture content. The permanent wilting point was calculated as 1/3 of the field capacity (Laar et al., 1992).

The saturated moisture content and bulk density were determined from core samples partly submersed in water for 24 hours and the moisture content obtained gravimetrically.

To determine the spatial distribution of water along the furrow, the following measurements were carried out on two selected furrows with different slopes; the infiltration opportunity time from the advance and recession times, inflow-outflow using flumes and the infiltration properties of the soil using a single ring infiltrometer. The information from the infiltrometer was used to determine the parameters in the modified Kostiakov equation (Walker and Skogerboe, 1987). The infiltration opportunity time and the infiltration equation were then used to obtain the infiltrated depth profile along the furrow. The furrow slopes in Farm 1 were in general, more gentle compared to those in Farm 2. With all cultural practices and the soil being the same on both farms, the differences in efficiency performance parameters and yields on the two plots was attributed to the slope differences.

Results and Discussions

Efficiency Performance Parameters

For a 2-day irrigation interval, the required depth of irrigation was determined to be 10 mm. **Table 1** presents the average measured performance parameters for the irrigation of the two plots. Detailed results are provided by Fonteh et al. (1998). The values presented on the table are average values from 13 evaluations on Farm 1, and 10 evaluations on Farm 2. The results on **Table 1** show that Farmer 1 applies on the average 35% more water than Farmer 2 during each irrigation. This is linked to the higher irrigation time on Farm 1. Though Farmer 1 applies more water, the tail water ratio on Farm 1 is lower. All these variations are due to the differences in the furrow slope between the two farms. This meant that the advance is faster in Farm 2, reducing the infiltration opportunity time and the time workers have to lift water onto the ridges. Very little water was therefore applied on steep slopes.

The average application efficiency for the two fields is 63.5%. This value is very good considering the target value of 40 -70% suggested by Walker (1980). For the particular soil at the site with very high infiltration rates, the traditional method of large furrows is very efficient following the irrigation interval of 2 days. On a different soil type, with low values of infiltration rate, the water applied manually on the ridges might be insufficient to meet the crop water requirements. For such cases, the requirement efficiency will be significantly less than 1 following a 2-day irrigation interval. To avoid this, the irrigation might have to be scheduled daily. The performance of the irrigation on Farm 1 could be improved by increasing the irrigation interval to say 3 days. This is because of the higher applied depths due to the gentler slope.

Effect of Slope

Due to the different furrow slopes on the two farms, the speed of water across the field and the distribution of infiltrated depth on the two farmers' fields were different. This contributed to variation in yields between the two plots. **Figures 2a** and **2b** show the measured distribution along the field for two different slopes. **Table 2** gives the main differences in the field characteristics, the distribution uniformity and the yield on both fields.

Where the slope is high (2.6%), the advance was very rapid. The recession was also fast at the top end of the field and so very little water in-

Table 1. Average Performance Parameters for 400 m2 Plots from Two Farms

Farmer	Average depth applied per irrigation (mm.)	Irrigation Interval (days)	Application Efficiency, Ea (%)	Tailwater Ratio, TWR (%)	Deep Percolation Ratio, DPR (%)	Duration of each irrigation per plot (min)
Farmer 1	19.0	2	56.0	0	44.0	74
Farmer 2	14.0	2	71.0	4	25.0	56
Average	16.5	2	63.5	2	34.5	

Note: a) The requirement efficiency was 100% in both cases; i.e., sufficient water was applied to meet the crop water requirements. b) The TWR is not always zero because of over-topping of the ridges.

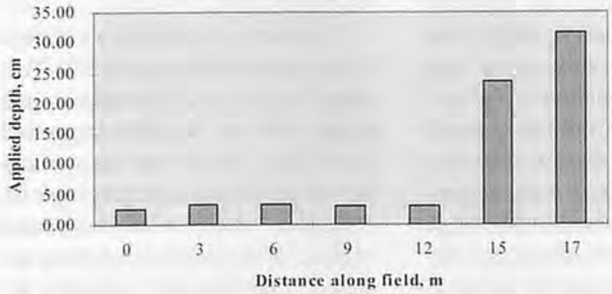


Fig. 2a Distribution of water along a large ridge irrigated field with a 2.6% slope.

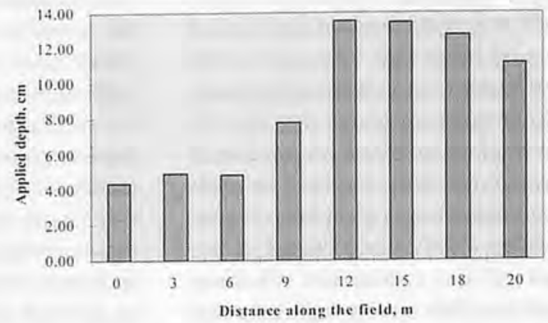


Fig. 2b Distribution of water along a large ridge irrigated field with a 0.83% slope.

filtrated at the top end of the closed-ended field. This is consistent with the very low distribution uniformity of 29% on Farm 2 with a slope of 2.6% compared to Farm 1 where the slope was 0.83% and the distribution uniformity 51%. These values of DU fall far below the accepted target values of 80 - 90% (Walker, 1980). Though the distribution is poor in Farm 1, the fact that there is over irrigation ensures that the crops are not stressed anywhere along the field. In Farm 2, the crops were under-irrigated and in addition the distribution uniformity was poor. The effect of the poor distribution and under-irrigation was that the crops visually looked healthier and greener at the bottom of the field compared with the top of the field. This had a significant influence on the yields of green peas. **Table 2** shows that, on the average, the yield on the plot with a gentler slope was about 40% higher.

The above suggests that when large ridges are used, the slope should be as low as possible. Due to the high momentum of the incoming water into the furrows, the slope could be set to zero. A very gentle or no slope will increase the advance and recession times along the field, give the irrigators enough time to lift sufficient amount of water onto the ridges and finally give a good distribution of water along the field. For fields without constant downhill slopes, the ridges should be constructed on a contour. This will however, increase the production cost since more effort will be required to make the ridges along a contour.

The large-ridge system was found to be more labour intensive as compared to open-ended small furrows with gated pipes (Fonteh et al., 1998). Irrigation with a large-ridge system required two persons to operate, compared to one with a gated pipe system. However, the gated pipe method required a higher initial amount of investment. The large furrows were found to reduce the chance of over toping, especially in the loose soils at the experimental site and were simple and robust to operate.

Conclusions

Based on the data collected and the analysis of results we can conclude that:

1. Contrary to conventional engineering wisdom, the simple, low technology, low cost, large ridge furrow irrigated system has a very good application efficiency averaging 63% for high infiltration rate soils.
2. The application efficiency can be improved if the farmers have simple devices such as tensiometers and resistance units to assist in irrigation scheduling thereby reducing the amount of over-irrigation.
3. The slope along the furrow has a considerable influence on the performance parameters and on the yield of green peas. With all factors being equal, the plots with a slope of 0.83% had a yield 40% higher that those with a 2.6% slope.
4. The slopes of the furrow should be preferably zero. Where the slope of the land is irregular, the furrows should be made along the contours.

Table 2. Field Characteristics, Uniformity of Application and Yield From Furrows with Different Slopes

Variables	Farmer 1	Farmer 2
Time of cut off (min)	4.5	2.33
Inflow rates (lps)	1.49	1.49
Field length (m)	20	17.5
Slope (%)	0.83	2.6
Average applied depth (mm)	19	14
Coefficient of variation of applied depth along the furrow	0.45	1.21
Distribution uniformity (%)	51	29
Yield (tons/ha)	6.8	4.5

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(Continued on page 42)

Tractor Tractive Performance as Affected by Soil Moisture Content, Tyre Inflation Pressure and Implement Type

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Abstract

A study was conducted to investigate the effect of a heavy clay soil moisture content and tyre inflation pressure (25 Psi and 35 psi) on two wheel field tractor tractive performance, when linked to two primary tillage implements (disc and chisel ploughs).

The chisel plough recorded the highest tractive force (11.5 Kn) and tractive power (17.3 Kw) in the moist soil with reduced tyre pressure. The differences between the effects of soil moisture content, tyre inflation pressure and implement type on the tractive force and power were highly significant at 0.01 level.

The highest coefficient of traction and tractive efficiency values were obtained with low tyre inflation pressure. The differences between the effects of treatments on the tractive efficiency were highly significant at 0.01 level.

Both implements recorded high rear wheel slippage on the moist soil with high tyre inflation pressure. The differences between the effects of soil moisture content, tyre inflation pressure and implement type on wheel slippage was highly significant at 0.01 level.

Introduction

Machinery application in agriculture has been one of the most advanced developments in agricultural production. Land preparation with tillage implements is the main mechanization expensive operation, which consumes large amounts of power and energy inputs. Therefore, the economical machinery and power selection is an acknowledged way to maximize profit and minimize total energy requirements and, consequently, cost of production. The proper selection of suitable implements to match the tractor power can reduce energy loss and optimize the tractor tractive performance in the field (Ismail et al, 1981; Erickon and Larson 1983).

Traction is a force derived from the interaction between a traction device (wheel or track) and the soil in order to facilitate motion. The magnitude and the nature of the force depend to a large extent on the characteristics of both soil and the tractive device.

The tractor tractive performance may be evaluated by means of a pull-slip test. The tractor must ensure small slip but large tractive force to be efficiently utilized through implement draught (Witney 1988; Baloch *et al* 1991). Shebi *et al* 1988 indicated that the drawbar pull increases with the increase of static load, area of contact between the rear wheel and the soil and with tractor speed.

The maximum tractive effort by the tractor wheels can occur when Coulomb's equation for shear strength is satisfied (Reece 1971). Mickelthwaite modified the equation for maximum tractive force as follows:

$$F_{max.} = AC + W \tan Ø$$

Where:

Fmax = maximum tractive force (Kn)
A = area of ground contact (m^2)
C = soil cohesion force (Kn/m^2)
W = applied load on the wheels (Kn)
Ø = angle of shearing resistance(°)

Saleque and Jangiev (1990) concluded that the waste of energy in tractors was reduced when wheel slippage was adjusted between 15-18%.

The tractive efficiency of the tractor depends on the nature of the soil surface, contact area of the track or tyre and the wheel weight (John Deere 1975). Bukhari *et. al* (1986) reported that the coefficient of traction is used for evaluation of the tractor tractive performance as affected by soil type and physical condition, moisture content and soil distribution pressure. The coefficient of traction is relatively higher in hard soil than sandy soils. It increases with soil moisture content (Kubota 1980). Mohamed and Clough (1988) concluded that to improve the tractive performance of a tractor is to reduce power losses at the soil-wheel interaction.

The objective of the present study is to investigate the effects of soil moisture content and tyre inflation pressure on a two-wheel tractor tractive performance when linked to two primary tillage implements.

Materials and Methods

The experimental work was conducted at the Butana Dairy Farm South of Khartoum State, Sudan in May 1998. An area of 1.28 ha was selected for the experiment and the soil was classified as heavy clay with low fertility. The moisture content and the soil bulk density of the area at three depths are given in **Table1.**

Experimental Layout and Design

The experimental area was divided into two main blocks (210 × 30 m), one was left dry (M.C. 4.32%) while the other was given light irrigation to maintain the required moisture content (11.24%). Each block was divided into three subblocks (210 × 10m) representing the replicates. Each subblock was divided into four plots giving a total of 24 plots.

A nest factorial design was used and the following treatments were randomly distributed within each replicate:

8- Disc plough in dry soil with lower tyre pressure (DLP_1)

2- Disc plough in dry soil with higher tyre pressure (DLP_2)

3- Disc plough in moisten soil with lower tyre pressure (DHP_1)

4- Disc plough in moisten soil with higher tyre pressure (DHP_2)

5- Chisel plough in dry soil with lower tyre pressure (CLP_1)

6- Chisel plough in dry soil with higher tyre pressure (CLP_2)

7- Chisel plough in moisten soil with lower tyre pressure (CHP_1)

8- Chisel plough in moisten soil with higher tyre pressure (CHP_2)

Two tractors were used in the experiment, namely; MF275 (70Hp) as a tested tractor and MF290 (80Hp) as an auxiliary source of power to pull the former tractor during the test. Two primary tillage implements were used, a disc plough of three cutting units and a chisel plough with five legs. Other tools and equipment used in the study included a hydraulic dynamometer, steel chain, meter tape (20m), ranging poles, scale tape (2m), stop watch, graduated cylinder and a fuel jerkin.

Parameters Measurements

Soil moisture content was measured by taking samples from three depths 0-10cm, 10-20cm and 20-30cm at three different locations randomly selected in each of the two blocks. The moisture content was calculated using the following formula:

$$M.C.\% = \frac{W1 - W2}{W_1} \times 100$$

Where:

W_1 = weight of wet soil sample (gm)

W_2 = weight of oven dry soil sample (gm)

To determine the soil bulk density, samples were taken from three depths as mentioned before. The soil samples were collected in cylindrical cores and the bulk density was determined as follows:

Soil bulk density (g/cc) = M/V

Where:

M = mass of the soil contained in the soil sampler (g)

V = volume of the cylin. Core base (cc) = $d^2L/4$

d = diameter of the cylin. core base (cm)

L = length of the cylin. core (cm)

The tractive force of the tractor was measured by attaching a hydraulic dynamometer to the front of the tested tractor on which the implement was mounted. The auxiliary tractor was used to pull the tested tractor through a steel chain and the dynamometer. Then the tractive force was measured as suggested by Bukhari *et al* (1988).

The travel speed of the tractor was determined for a distance of 210m using the measuring tap, ranging poles and pegs. The time required to cover this distance was recorded by a stop watch. The speed in Km/h was then calculated.

The tractive power was calculated by the following equation as suggest by Kepner *et al* (1982):

Tractive power (kw) =

drawbar pull (kn) × speed (km/h)

The coefficient of traction was computed from the following relation (Dwyer and Pearson, 1976):

$$\text{Coeff. of traction} = \frac{\text{drawbar pull (kn)}}{\text{Dynamic load on the rear wheels (kn)}}$$

The dynamic load on the rear wheels =

static weight of rear wheels + weight of the implement + weight transferred from the front axle.

Weight transferred from the front axle = Ws – Wd

Where

Table 1. Soil Moisture Content and Bulk Density of the Experimental Area

Soil depth	Low moist M. C.(%)	Soil B.D.(g/cc)	Highly moist M. C.(%)	Soil B.D.(g/cc)
0 - 10 cm	3.38	1.8	10.36	1.62
10 - 20 cm	4.44	1.77	11.31	1.60
20 - 30 cm	5.14	1.77	12.04	1.57

M.C. = moisture content.
B.D. = Bulk density.

Ws = static weight of front wheels
Wd = dynamic weight of front wheels after attachment of the implement

The tractive efficiency of the tractor was determined from the following equation:

$$\text{Tractive efficiency(\%)} = \frac{\text{drawbar power (kw)}}{\text{Engine output to the final drive axle (kw)}}$$

The final drive axle power = engine output – transmission loss

The tractor rear wheel slippage was measured by marking the wheel at a portion tangent to the ground surface. Four distances each covered by 10 revolutions of the wheel when the tractor was unloaded or loaded with the implement were measured. Slippage was calculated according to Person (1969) as follows:

Slippage (%) = (Distance traveled unloaded – Distance travel with load) × 100/Distance traveled unloaded

Results and Discussion

The effects of soil moisture content and tyre inflation pressure on a two wheel tractor tractive force, travel speed, tractive power, wheel slippage, coefficient of traction and tractive efficiency are given in **Tables 2** and **3.** The performance of the above parameters was investigated when the tractor was linked to the disc and chisel ploughs.

The statistical analysis of variance for the different treatments is illustrated in **Tables 4** and **5.**

It is clear that the chisel plough for both soil moisture contents gave the highest tractive force (**Table 2**).

Within the same moisture content, the lower tyre inflation pressure gave the highest tractive force for both implements. The difference in tractive force between the two soils at higher tyre pressure was 1.30 kn and 0.50 kn for the disc and chisel plough respectively, while this difference at low tyre pressure was 1.20 kn for the disc plough and 1.10 kn for the chisel plough. The differences between the treatments were highly significant at 0.01 level. The lower tractive force recorded by the two implements in the dry soil with high tyre inflation pressure may be due to high slippage experienced under these conditions. This result is in agreement with that of Dwyer(1973) and Czako (1974).

The tractive force of the chisel plough was usually higher than that of disc plough, which could be due to larger width of cut and depth of ploughing. This agrees with the findings of Baloch *et al* (1991) and Senkowski (1963).

The interactive effect of the soil moister content, tyre inflation pressure and implement type on the tractive force was not statistically significant (**Table 4**).

The highest speed of travel (5.90 km/h) was given by the disc plough in the dry soil with low tyre inflation pressure while the lowest speed (4.90 km/h) was recorded by the chisel plough in the highly moistened soil with high tyre inflation pressure. This could be due to the rotating effect of the disc elements on the disc plough and the weight and depth of cut of the chisel. This coincides with the findings of Kepner *et al*(1982); Shebi *et al* (1988).

The chisel plough with lower tyre inflation pressure recorded the greatest tractive power and the values were 17.30Kw and 16.0Kw for dry and moisten soils, respectively. This is due to the higher tractive force and low slippage resulted from the larger ground contact area. These findings are in accordance with that of Shebi *et al* (1988) and

Table 2. Effect of Soil Moisture Content, Tyre Inflation Pressure and Implement Type on Tractive Force, Travel Speed and Tractive Power

Item	C_1						C_2					
	P_1			P_2			P_1			P_2		
Impl.type	TF	SP	TP	TF	SP	TP	TF	SP	TP	TF	SP	TP
Disc	8.9	5.9	14.5	7.8	5.6	12.2	10.1	5.5	15.4	9.1	5.5	13.6
Chisel	10.4	5.5	16.0	9.1	5.6	14.2	11.5	5.4	17.3	9.6	4.9	12.6

C_1 = dry soil(3.32%), C_2 = moisten soil(11.24).
P_1 = low tyre inflation pressure(25psi), P_2 = high tyre inflation pressure(35psi).
TE = tractive force, SP = travel speed, TP = tractive power.

Table 3. Effect of Soil Moisture Content, Tyre Inflation Pressure and Implement Type on Wheel Slippage, Coefficient of Traction and Tractive Efficiency

Item	C_1						C_2					
	P_1			P_2			P_1			P_2		
Impl.type	SL	CT	TE	SL	CT	TE	SL	CT	TE	SL	CT	TE
Disc	8.9	55.2	76.7	9.9	48.8	73.7	12.7	63.4	66.8	14.3	56.9	62.8
Chisel	9.7	64.9	76.6	10.8	56.8	73.3	13.6	71.7	66.1	15.3	62.2	60.0

C_1 = dry soil, C_2 = moisten soil.
P_1 = low tyre inflation pressure, P_2 = high tyre inflation pressure.
SL = wheel slippage, CT = coefficient of traction, TE = traction efficiency.

Table 4. Analysis of Variance for the Different Treatments Affecting Tractive Force, Travel Speed and Tractive Power

Parameters	TF			SP			TP		
Source of Variation	Fcal.	Ftab. 5%	Ftab. 1%	Fcal.	Ftab. 5%	Ftab. 1%	Fcal.	Ftab. 5%	Ftab. 1%
Soil M. C.	148.3**	4.75	6.33	5.05**	4.75	6.33	18.93**	4.75	6.33
Implement I	284.3**	4.65	6.33	2.25	4.65	6.33	6.09**	4.65	6.33
Tyre press P	490.2**	4.65	6.33	1.69	4.65	6.33	15.11**	4.65	6.33
M. C. × I	2.8	4.65	6.33	0.24	4.65	6.33	0.41	4.65	6.33
M. C. × P	0.31	4.65	6.33	0.002	4.65	6.33	0.001	4.65	6.33
I × P	11.58**	4.65	6.33	0.0002	4.65	6.33	0.1	4.65	6.33
M. C. × P × I	1.9	4.65	6.33	0.85	4.65	6.33	0.05	4.65	6.33

Ftab. = F tabulated, Fcal. = F calculated.
M.C. = Moisture content, P = Tyre inflation pressure.
I = Implement type.
** = Highly significant.

Witney (1988).

The tractive power recorded by the chisel plough under the low tyre inflation pressure was higher than that of disc plough by 12% and 6.4% for the dry and moisten soil, respectively. **Table 4** shows a highly significant difference between the effects of soil moisture content and tyre inflation pressure at 0.01 level while for the implement type the difference is only significant at 0.05 level.

The relationship between the tractive force and the tractive power is shown in **Fig. 1**. Both implements recorded higher rear wheel slippage in the moist soil with high tyre inflation pressure and the values were 15.3% for the chisel and 14.3% for the disc plough (**Table 3**). This could be due to the small area of contact with the soil and the wetness of the soil. This agrees with the findings of Berger *et al.* (1963) and Raghaven *et al* (1977).

The chisel plough recorded a higher wheel slippage than the disc plough for all treatments. The observed increase in slippage of the chisel plough as compared to the disc plough was 9% in the dry soil for the lower and high tyre inflation pressure, while in the highly moistened soil, the increase was 7% for both tyre inflation pressures. Such differences between the treatments were highly significant at 0.01 level (**Table 5**).

The higher slippage for the chisel plough may be due to the weight of the implement and depth of cut. The relationship between the travel speed and wheel slippage for the different treatments is given in **Fig. 2.**

The highest coefficient of traction (71.7%) was obtained by the chisel plough in the moistened soil and for the low tyre inflation pressure, while the lowest coefficient of traction (48.8%) was recorded by the disc plough in the dry soil with high tyre inflation pressure. This could be due to the decreasing pull from the low shearing strength. This is in agreement with the findings of Czako (1974) and Kepner *et al.* (1982). The differences between the effects of soil moisture content, tyre inflation pressure and implement type on the coefficient of traction were highly significant at 0.01 level (**Table 5**).

Table 5. Analysis of Variance for the Different Treatments Affecting Wheel Slippage, Coefficient of Traction and Tracive Efficiency

Parameters	SL			CT			TE		
Source of Variation	Fcal.	Ftab. 5%	Ftab. 1%	Fcal.	Ftab. 5%	Ftab. 1%	Fcal.	Ftab. 5%	Ftab. 1%
Soil M. C.	549.5**	4.75	6.33	108.8**	4.75	6.33	228.8**	4.75	6.33
Implement I	38.35**	4.65	6.33	232.8**	4.65	6.33	21.86**	4.65	6.33
Tyre press P	39.50**	4.65	6.33	381.6**	4.65	6.33	264.2**	4.65	6.33
M. C. × I	1.11	4.65	6.33	2.92	4.65	6.33	9.29**	4.65	6.33
M. C. × P	0.17	4.65	6.33	0.08	4.65	6.33	4.14	4.65	6.33
I × P	0.02	4.65	6.33	11.95**	4.65	6.33	13.42**	4.65	6.33
M. C. × P × I	0.05	4.65	6.33	6.63	4.65	6.33	0.07	4.65	6.33

Ftab. = F tabulated, Fcal. = F calculated.
M.C. = Moisture content, P = Tyre inflation pressure.
I = Implement type.
** = Highly significant.

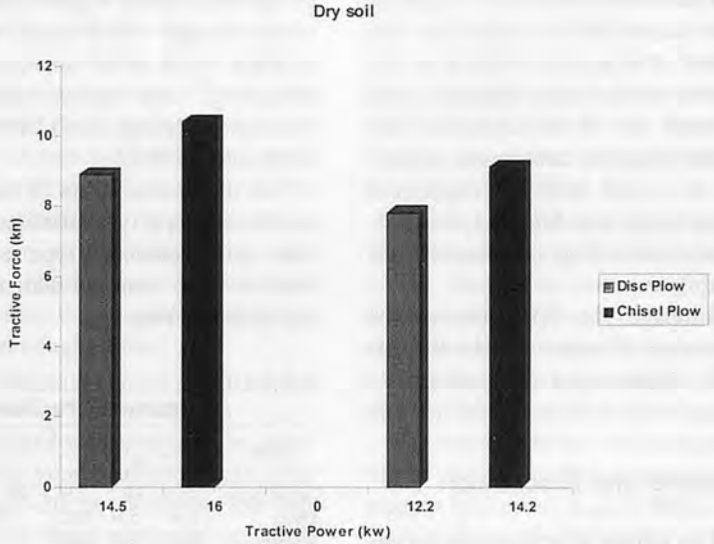

Fig. 1 Relationship between the tractive force and the tractive power.

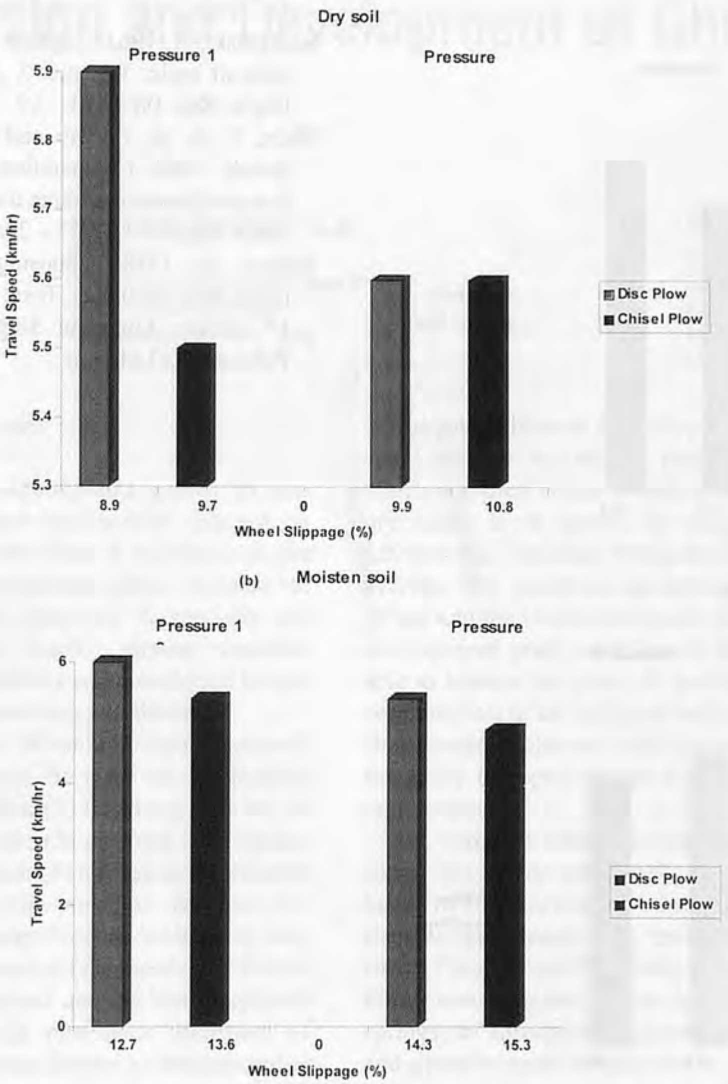

Fig. 2 Relationship between the travel speed and the wheel slippage.

The highest tractive efficiency values of 76.7% and 76.6% were recorded in the dry soil with lower tyre inflation pressure by the disc and chisel plough respectively. This could be due to low slippage and high forward speed resulting in high available power at the rear axle of the tractor. This result agrees with the findings of Mohamed and Clough (1989) and Liljedahal *et al.* (1976).

The lowest values of the tractive efficiency were 60.0% and 62.8% in the moist soil with high tyre inflation pressure for the chisel and disc plough respectively. This could be due to high slippage and excessive rolling resistance in the moisten soil. This is in accordance with the findings of Shebi *et al.* (1988) and Baloch *et al.* (1991). The differences between the effects of these treatments were highly significant at 0.01 level. The difference between the interactive effects of the parameters was not statistically significant.

The relationship between the tractive power and the tractive efficiency is illustrated in **Fig. 3.** It can be observed that for the different treatments, the tractive efficiency increases with an increase in the tractive power.

Conclusions

1. The tractive force of the tractor is higher and the wheel slippage is lower with reduced tyre inflation pressure.
2. The tractive power exerted by the tractor increased was the tractive force is increased.
3. The maximum tractive efficiency is obtained in the dry soil with low tyre inflation pressure.
4. The chisel plough usually records higher values of tractive force, tractive power, wheel slippage, travel speed, coefficient of traction and tractive efficiency as compared to the disc plough for the different treatments.

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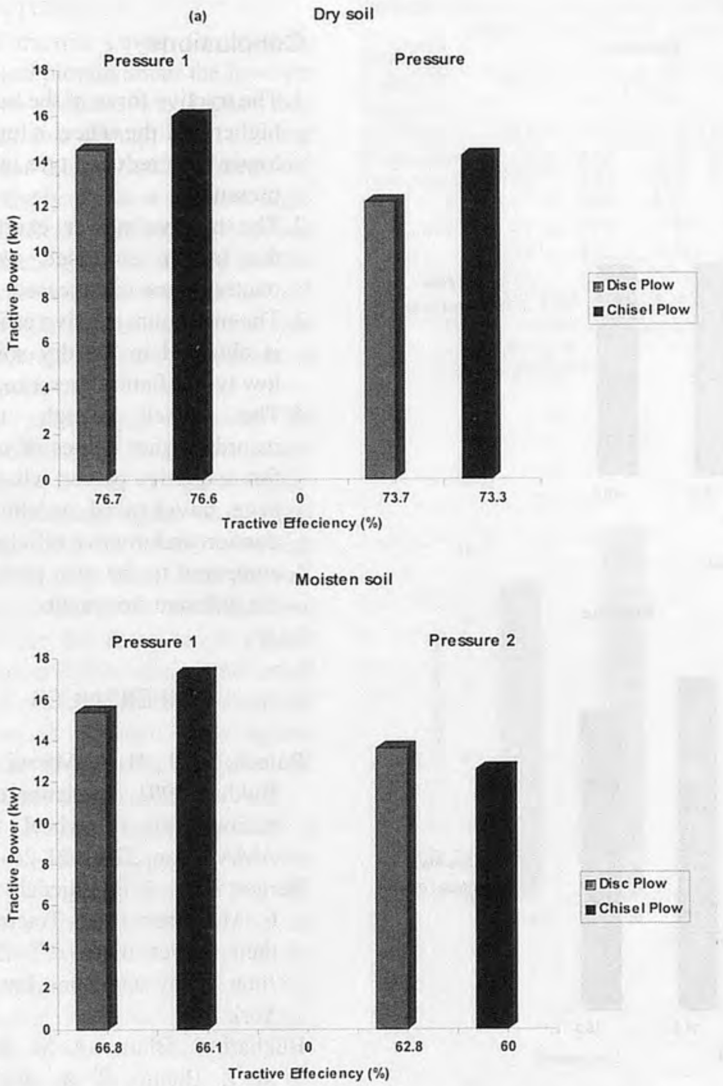

Fig. 3 Relationship between the tractive power and tractive efficiency.

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Design and Development of Chickpea Combine*

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Abstract

Chickpea plants grown in Iran are short and mostly cultured on rough dry land. It is difficult to use a conventional grain combine to harvest chickpea. A specially designed tractor drawn machine (PCombine) was developed to suit the harvesting conditions.

The PCombine simultaneously performs the tasks of: (1) picking pea pods; (2) threshing peas out of the pods; (3) cleaning and separation, and; (4) unloading the cleaned peas. The machine features: (1) three way flotation which was very important to the header to follow the contour and the land irregularities; (2) pneumatic transport of pods from header to thresher rather than the usual feed chain conveyor in the conventional grain combines; (3) pneumatic unloading of clean peas instead of using augers or other mechanical transport means; and (4) elimination of straw walker. The machine was tested in the field with good results although further improvement is needed to reduce the rather high head losses.A field capacity of 0.35 ha/hr was achieved. The total power requirement was 13.7 kW.

Introduction

Chickpea plants in Iran are cultivated mostly as fallow product which is typical in the Middle East dry land. It is grown in some 650,000 ha., yielding 800kg/ha as average. The plants are as short as 30 cm and the land is too rough for conventional grain combines to be able to harvest the pods. A special combine had to be designed with a short header width and with proper flexibility to cope with the land irregularities.

The common cutter bar headers could not work efficiently at a height of 10 cm or less. A rather new stripper type header was used instead. Three means for header flexibility was designed: a pair of coil springs, an adjustable height wheel and a header width of 100 cm.

A finger type thresher was used but pods were thrown from header to thresher instead of being transported by feed-chain conveyors as usually done in conventional combines. Straw walkers were omitted because not much straw was expected in chickpea harvesting with the stripper type header. A chaffer and sieve were used as separation and cleaning unit. Unloading took place pneumatically from a collecting funnel to the sacker unit.

Operational System and Component Designs

Operational System Designs

The PCombine system was designed as a tractor-drawn machine instead of self-propelled system for easier manipulation in the rough terrain. The details of the system design and components are illustrated in **Figure 1**. With the tractor hand throttle set at 540 rpm PTO speed,

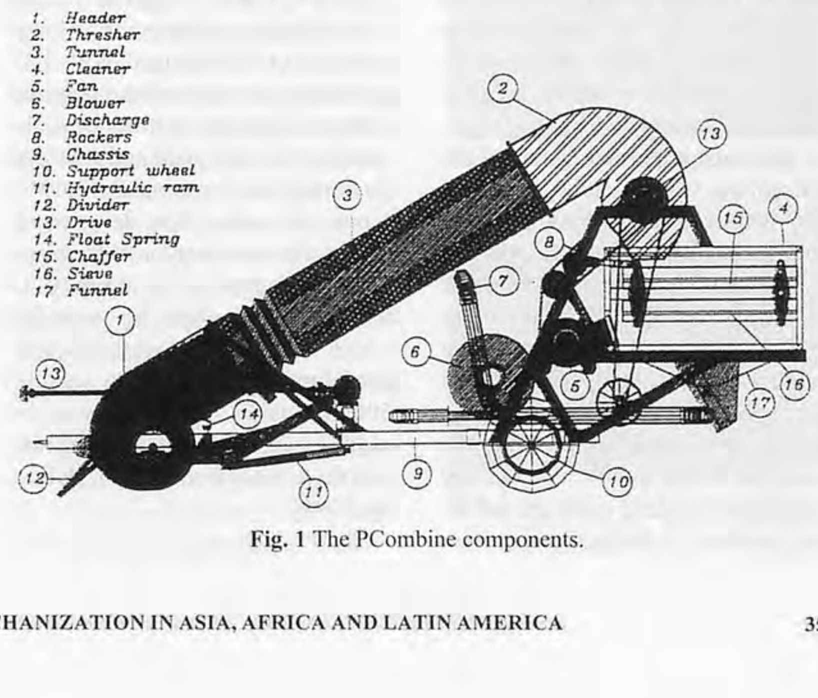

Fig. 1 The PCombine components.

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the machine will be pulled by a froward speed of about 5 km/hr. Assuming a field efficiency of 0.7, the field capacity can be estimated based on Equation (1) [Hunt, 1995]:

$$C = Swe/10 \quad (1)$$

Where

C = field capacity, ha/hr

S = forward speed, km/h

w = efficient working width, m

e = field efficiency, decimal

Substituting the data for w and e, the machine will theoretically harvest 0.35 ha/hr. The strippers comb the peapods from the plants and throw them toward the thresher at a height of 2.40 m above and 3.54 m away from the head cylinder center. The lowest position of the cylinder center axis from ground can be 0.30 m.

The picked pods are thrown into the thresher with the help air flow generated by the strippers. The thresher cylinder fingers rotate in between the concave fingers to thresh the peas out of their pods. Peas and MOG flow on the chaffer in the separator-cleaner compartment where debris are carried out of the combine by reciprocating action of the chaffer. Cleaned peas and chaffs fall down the chaffer and on the sieve. The chaffs are blown by a fan and clean peas after passing the sieve holes are collected in the funnel underneath. Both chaffer and sieve were of the adjustable type. A venturi structure under the funnel receives the clean peas. A blower blows air into this structure to convey the peas out into a sacker device.

The most important feature of the PCombine was its ability to adjust the header to accommodate short chickpea plants. This task was accomplished by three means: a pair of tube springs, an adjustable height front wheel and the narrow working width. These components give enough working flexibility and flotation to the header to comb the plants at as low as 10 cm or less and yet follow the land contours and irregularities. A hydraulic ram was implemented for lifting the header while in transport mode.

System Component Designs

1. Header: The header is a stripper type [Kepner et al,1977; Shelbourns Reynolds Eng. 1989; Zheo and Shou, 1992] with a rotor having 8 strippers around the perimeter; designed to pick peapods and throw into the thresher. Efficient working width was 0.98 cm. The rotor speed at no load was 635 rpm. The rotational speed of the header should be high enough for every stripper to comb the height of 35 cm while passing chickpea plants and yet be able to throw the pods through the tunnel to the thresher. The tunnel was set at 30° with respect to horizon and has a length of about 4 m. The stripper linear speed in an experiment [Shelbourns Reynolds Eng., 1989] was determined as 17 m/s. With this speed for the cylinder of 60 cm in diameter, the rotational speed runs to about 541 rpm. The friction against tunnel walls and the associated pressure drop cause an overall height drop of 60% [Kepner et al, 1977]. Therefore, the effective length of the tunnel to be considered was 4/0.4=10 m. The horizontal and vertical distance for the trajectory may be obtained from the following equations:

$$x = v_o \cos(30°)t \quad (2)$$

$$y = v_o \sin(30°)\, t - g\, t^2/2 \quad (3)$$

substituting $x = 10$m and $v_o = 17$ m/s in Eq.(2), $t = 0.68$ s and thus $y = 3.47$ m which is far beyond the required 2.40 m height of the thresher. Considering the crop yield and combine forward speed, a material flow of 1N/s into the header was determined. The power consumption of the stripper was assumed to be the same as that for cutting alfalfa by cutter-bar which was 1.2 kW/m width of stripper [Hunt, 1995]. A hollow shaft of 30mm outside diameter was to be used. An inside diameter of 20 mm was determined from Eq. (4) [Hall, et al., 1991]:

$$d_o^3 = 16/(\pi\tau_s(1-k^4))\sqrt{(K_bM_b)^2+(K_tM_t)^2} \quad (4)$$

where

τ_s = 55 MPa

K_b = 3

M_b = 89.25 Nm

K_t = 3

M_t = 38.5 Nm

$K = d_i / d_o$

d_i = inside dia., m

d_o = outside dia., m

A d_i value of 20mm was the result.

2. Thresher: The thresher is finger type with 6 rotating finger bars around the perimeter of the thresher cylinder. The concave has 5 rows of fingers. The rotor rotated at a speed of 477 rpm. The cylinder diameter and linear speed for the grain combine are reported, respectively, as 375-400 mm and 25-30 m/s [Kepner et al., 1977]. The experiments result was a 4.7 m/s linear speed for edible bean. Some stated these values are as 380-560 mm and 3-44 m/s. and recommended a linear speed of 10-15 m/s for threshing peas [Srivatsava et al., 1993]. With a choice of 600 mm for the cylinder diameter and a linear speed of 15m/s the rotation speed of the cylinder (n_{thr}) in rpm was calculated from Eq.(5)

$$n_{thr} = v_t/\pi D = 15 \times 60/(3.14 \times 0.6) = 477 \text{ rpm} \quad (5)$$

where

n_{thr} = thresher cylinder speed, rpm

v_t = cylinder linear speed, m/s

D = cylinder diameter, m

A hollow shaft of the same dimensions for the header are calculated from Eq. (4) which was also adequate for the thresher cylinder.

3. Separator and Cleaner: These components include a chaffer on top of a sieve which counter reciprocate at 90Hz to separate the chaff from clean peas. A fan at 540 rpm then blows the chaff out of the rear of the combine. A collecting funnel underneath, collects the clean peas into a venturi structure for discharging to a sacker. A pair of rocker arms rocks the chaffer and sieve.

Grain combines usually have 114-147 cm^2/m width for the thresher cylinder when one chaffer and one sieve are used [Srivatsava et al. 1993]. The same values were used for a 98cm long PCombine thresher. A JD 955 grain combine's chaffer and sieve each with 97 cm width and 140 cm in length were implemented. A special pair of rockers were designed and rocked by the pair of JD 955 combine's rocker arms. The rocking amplitude and frequency were calculated at 30 mm and 4.5 Hz, respectively.

The cleaner fan design calculations starts with Eq.(6) [Srivatsava et al., 1993],

$ma = F_g - F_d$ .... (6)

where

m = grain mass, kg

a = grain acceleration, m/s^2

F_g = force of gravity, N

F_d = drift force on the grain, N

and,

$F_d = C_d v_y^2$........................ (7)

where

C_d = drift coefficient

v_y = vertical component of grain relative velocity with respect to air, m/s

Also true that,

$F_d = mg = C_d v_t^2$.................. (8)

where

v_t = grain terminal velocity, m/s

Eliminating C_d from the above two formulas yields,

$F_d = mg(v_y/v_t)^2$ ....(9)

As a result, 4 fan blades each with 9 cm × 98 cm dimensions at a rotational speed of 540 rpm will produce 2 m^3/s at a velocity of 10 m/s through an outlet of 98 cm length by 20cm width.The fan's outside diameter was determined to be about 35 cm. Such a volume of air was theoretically enough to separate the grains from chaffs.

4. Tunnel: A rectangular tunnel of 2.91 m long at 30° with respect to horizontal, was designed to form a passage through which the pods flow from header to the thresher. To better transport the leaves and other light materials, the tunnel was formed into a venturi shape in order to create a pressure-drop against the wind blown from the header.

5. Discharge: The clean peas inside the venturi structure were designed to be blown into a sacker unit for sacking.

6. Chassis: The chassis includes a height adjustment wheel and a divider in front, a couple of supporting wheels at rear, a lifting hydraulic ram and a pair of tube springs for header flotation.

7. Drive System: The machine was a trailed PTO driven type. B type twin V belts and pulleys were used to drive the header and thresher while B type single V belts were implement to rocker arms, fan and blower.

Results and Discussion

The PCombine was specially designed for the dry farming. **Figure 2** shows a photo of the combine. The machine weighed about 13.5 kN. It was 2.70 m tall, 2.60 m wide and 5.5 m long. It was tested in the furrow-irrigated field at Tehran University. Inspite of the worst field condition due to the furrows, the machine performed so well that it bared the plants out of pods and more interesting, it left the chick pea stems and weeds on the ground. However, considerable header loss was observed which should be reduced through further investigations. The chickpea plant and field conditions as well as a view of the chickpea field before and after harvesting by PCombine are respectively shown in **Figures 3**, **4** and **5**.

The power requirement for various system components can be evaluated as follows:

1. Header: The total power requirement for the header can be obtained from Eq. (10),

$P = Tn/9549 = 2.56$ kW... (10)

where

P = power for rotational speed of the cylinder, kW

T = torsional moment = 38.5 Nm

n = rotational speed at no load = 635 rpm [Shelbourns Reynolds Eng. 1989].

The total power composed of two components; (A) power to strip and throw the pods and (B) air resistance against rotation of the stripper blades which can be calculated from Eq.(11) [Jones, 1989],

$P_w = 0.0005 D^2 V^3$ .... (11)

where

P_w = power to produce wind, kW

D = outside diameter of header cylinder, m

Fig. 2 Assembled PCombine.

Fig. 3 A view of the chickpea farm.

Fig. 4 A view of the chickpea condition.

Fig. 5 Chickpea field before (left) and after (right) harvesting using PCombine.

V = wind velocity = stripper linear speed, m/s

By substitution of D = 0.6 m, V = 17 m/s in Eq.(11) the wind producing power component was 1.44 kW. Subtracting this value from the total power, 2.56 kW, gives the power component of 1.12 kW for stripping and throwing the pods.

2. Thresher: The power requirement was estimated at 3.2 kW /m length of thresher [Kepner et al., 1977]. However, part of this power is used to overcome the friction. The remainder of power that involves in actual threshing was calculated as follows,

$P_{thr} = M_t\, n/9549$ .... (12)

where

P_{thr} = power for threshing, kW

M_t = threshing torsional moment, Nm

n = thresher cylinder speed, rpm

Substitution of M_t = 41.37 and n = 477, gives 2.07 kW as the power for threshing alone. M_t was the difference between the total moment of 60 Nm and 18.63 due to friction.

A summary of calculated powers for other components as well as for header and thresher are shown in **Table 1**.

Assuming PTOP/iP=0.9, an iP= 0.57 kW are needed for propulsion of the combine components. Additional 3.1 kW should be made available for pulling the 13.5 kN weight of the PCombine and 2500 kg mass of tractor at 4.5 km/h. The rolling resistance against all wheels is assumed to be 0.05 and the tractor transmission efficiency of 0.75 is taken into account. The total iP = 13.67 kW (18.3 hp) is thus required for the machine operation.

The test results showed that the total indicated power of 13.67 kW (18.3 hp) was sufficient for the combine operation.

Table 1. Summary of Power Requirements for Different Components

Component	Power req'd (kW)	Total PTP (kW) (safety factor 1.5)	Speed rpm (no load)
Header	2.95	4.42	635
Thresher	3.20	4.50	477
Rockers	0.06	0.09	277
Fan	0.33	0.50	540

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Effect of Tool Geometry on Harvesting Efficiency of Turmeric Harvester

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Abstract

Turmeric is one of the important spice crops which earns sizable foreign exchange in India through export of its end products. Harvesting of turmeric rhizome is labour intensive, requiring skilled men labour to dig out the crop. The non-availability of such skilled labour and the high wages demanded by them to harvest the crop, the higher field losses and damage to the crop by manual harvesting, necessitate the need to develop a suitable mechanical harvester for turmeric. Power tiller is a multipurpose hand tractor designed primarily for rotary tilling and other operations. They are visualized as potential source of power on small farms due to their compact size and manoeurvability in narrow and also cropped fields. To satisfy the basic requirements of achieving maximum harvesting efficiency with minimum damage to the crop and at lesser cost the various design parameters namely blade shapes (crescent, straight and inverted V), rake angle (10, 15 and 20 deg) and lift rod length (450, 500 and 550 mm) were investigated and optimized. A prototype harvester with optimized design parameters was evaluated for its performance and the results are compared with the conventional method.

Introduction

Turmeric (*Curcuma Longa Linn.*) is one of the major spices cultivated in India in an area of 124,600 ha with a production of 487.6 lakh tonnes. The general practice in conventional method of harvesting is to wet the crop after removal of the cut foliage which are spread in the field for drying. The digging is done after 5 to 7 days of irrigating the field. The conventional practice is to cut the leaf shoots upon maturity and slightly wet the field. The turmeric rhizomes are dug out after a week by skilled labour with a special fork type of spade / pick axe. Normally turmeric digging is done by contract labour who demand very high wages during peak season. The charge demanded is very high and the damage caused to rhizome by the fork type spade is 10 to 15 per cent because the labour has to dig out the clump all around and in doing so, the fork bruises the rhizome every time it hits the rhizome. The present situation of migration of labour to various scholastic jobs and thrust for more production to feed the increasing population makes the harvesting during peak season a tiresome one. This situation necessitates the introduction of a suitable machine for harvesting turmeric rhizomes so that several losses could be avoided due to delayed harvesting. Hence, a power tiller-operated turmeric harvester was developed in the Department of Farm Machinery, College of Agricultural Engineering, TNAU, Coimbatore,.

Review of Literature

Misener *et. al* (1984) designed a two-row potato digger to dig, lift and load the potatoes. The digger blade shape was 250 × 130 × 60 mm high carbon steel which oscillated about the centre point. Ganshyam Das and Avinash Agarwal (1985) developed a concave shaped share plate for potato digger attachment to a country plow. Sharma and Sharma (1986 a and 1986 b) designed an improved prototype of tractor drawn oscillating potato digger and main emphasis was given for vibration control in the design. The blade was of the size 510 × 260 × 8 mm and for a single row operation the draft required was 80 to 105 kg. As the forward speed increased from 35.7 to 74.6 cm / sec, the damage to tubers increased from 0.3 to 0.7 per cent and the undug tubers increased from 6.6 to 14.4 per cent. Kang and Halderson (1991) also designed a two-row vibrating blade potato digger and they found that increased travel speed reduced the shatter bruise and black spot of potatoes because of more retention of soil on blade; that draft force decreased as vibrational frequency increased and travel speed decreased. Anon (1990) reported the cassava digger and sweet potato and turmeric lifter developed by Carib Agro Industries Ltd, Barbados. The machines undercut the crop deeply with strong shares and loosened the soil with metal fingers which reciprocated deeply beneath the crop. Duraisamy and Balasubramanian (1998) investigated a groundnut crop picker - conveyor attached to a tractor-drawn digger blade with two typical tools of geometry, inverted-V and crescent and at different rake angles from 5 to 20 deg. Maximum harvesting efficiency was achieved with crescent shaped tool with 15 deg rake angle.

Methods and Materials

The unit consists of a digging blade with three bar points for easy penetration into the soil. Lift rods are provided at the rear of the blade to handle the harvested rhizomes with the soil that is being pushed by the blade. The oscillating motion for the lift rods is effected through eccentric provided on either side of the unit. The eccentrics are connected to a shaft provided at the top portion of the unit. (**Fig.1**). The power is transmitted from the clutch pulley of the power tiller to a reduction gear box mounted near the hitch bracket assembly of the power tiller. From the gear box, the power is transmitted to the shaft of the turmeric harvester unit through V belt transmission. For harvesting, the bars penetrate into the soil along with the blade, lift the turmeric rhizomes along with the soil. When the dug rhizomes with the soil are pushed on to the lift rods, the oscillating motion separates the rhizomes from the soil. The rhizomes slip back to the ground and the dug out rhizomes get deposited on the soil. For controlling the depth of operation the wheels were provided on either side of the unit. The pneumatic wheels were replaced with a pair of special type cage wheels to accommodate the height of ridges.

Three shapes of the tool namely, straight, crescent and inverted V blades and three levels of rake angle 10,15 and 20 degrees and three levels of lift rod length 40, 45 and 50 cm were selected as variables to evaluate the harvesting efficiency and the damage to the rhizomes during harvesting with the unit. The field performance of the prototype harvester with the optimized parameters was conducted for three predominant varieties of turmeric in two types of soil.

The turmeric harvester was evaluated for harvesting three varieties, namely; Erode, Salem and BSR-1, in clay loam and sandy loam soils. The spacing adopted for the three varieties were 45 × 20 cm, 45 × 20 and 60 × 20 cm, respectively, for Salem, Erode and BSR-I. The forward speed of approximately 1.5 kph was obtained by selecting appropriate transmission ratio. Observations were made for three replications and the data were recorded. The harvester was operated in an area of 0.5 ha for each test. The performance of the unit was evaluated in terms of harvesting efficiency, field capacity, field efficiency, undug rhizomes and damage caused to the rhizomes. The harvesting efficiency was calculated using the following formula:

$$\eta_{ch} = (W_r / W_r + W_s) \times 100$$

where,

η_{ch} = Harvesting efficiency, per cent

W_r = Weight of rhizomes collected from harvesting clump per m^2, kg

W_s = Weight of undug rhizomes collected from the soil per m^2, kg

From the data collected from each plot, the coverage, cost of harvesting and harvesting efficiency were calculated.

The percentage of damaged or cut rhizomes in the harvested crop was determined by sampling 50 rhizomes at random and counting the number of damaged / cut rhizomes.

Percentage of damaged rhizomes,

$$D = N_c / N_t \times 100$$

where,

D = Damaged rhizomes, per cent

N_c = Number of damaged rhizomes

N_t = Total number of rhizomes in the sample

The above procedure was replicated thrice and all readings were tabulated. The soil properties soil type, soil moisture, bulk density, and cone index were recorded by using the standard procedures.

Results and Discussion

The mean soil moisture content during harvest varied from 9.47 to 13.52 percent. The bulk density of the sandy loam and clay loam soil was 1.417 and 1.523, respectively. The cone index of the soil varied from 4.23 to 5.56 kg/ cm^2. The depth of operation was in the range of 200 to 225 mm. The effect of rake angle on harvesting efficiency with the selected shapes of blade is depicted in **Fig. 3**. It is observed that the blade shape greatly influenced the harvesting efficiency. Of the three blade shapes, the use of crescent shaped blade resulted in a maximum harvesting efficiency at all levels of rake angle and lift rod

Fig. 1 Power tiller-operated turmeric harvester.

Fig. 2 Turmeric harvester in operation.

length. Also the 15-deg rake angle recorded higher harvesting efficiency irrespective of the blade shape and lift rod length. The effect of lift rod length on harvesting efficiency was clearly reflected in the crescent shaped blade with 500 mm lift rod length yielding higher value than the other two. The highest harvesting efficiency of 98.1 was obtained in crescent shaped blade with 15-degree rake angle and 500 mm lift rod length.

The effect of rake angle on damage caused to the turmeric rhizomes with different type of blades is shown in **Fig. 4**. The influence of blade shape in minimizing the damage was clearly reflected in the performance of crescent shaped blade whereas the reduction in damage caused to the rhizomes is marginal at all levels of rake angle and lift rod length for the straight and inverted V blades. The minimum damage was noticed at 15-deg of rake angle irrespective of the blade shape and lift rod length. The lowest value of damage caused to the rhizomes was 0.8 percent obtained in the crescent shaped blade with 15-degree rake angle and 500 mm lift rod length.

Hence a prototype harvester with optimized parameters of crescent shaped blade with rake angle of 15 deg and lift rod length of 500 mm was evaluated for its performance and compared with the conventional method of digging with spades. The performance results of the prototype turmeric are shown in **Table 1**.

The cost of operation of manual digging with fork type spades was Rs. 3950 per ha and the damage caused to the turmeric rhizomes was 5.47 per cent. When compared with manual digging the power tiller operated harvester results in 63.7 and 91 percent saving in cost and time. The damage caused to the rhizomes is 4.52 percent with the use of fork because the labour has to dig out the clump all around and in doing so, the fork bruised the rhizome every time it hits the rhizome as compared to 0.92 percent in the case of harvester. Also, the rhizomes left undug in the soil was 6.43 percent in the case of manual digging as against 1.76 percent with the power tiller operated harvester.

Conclusions

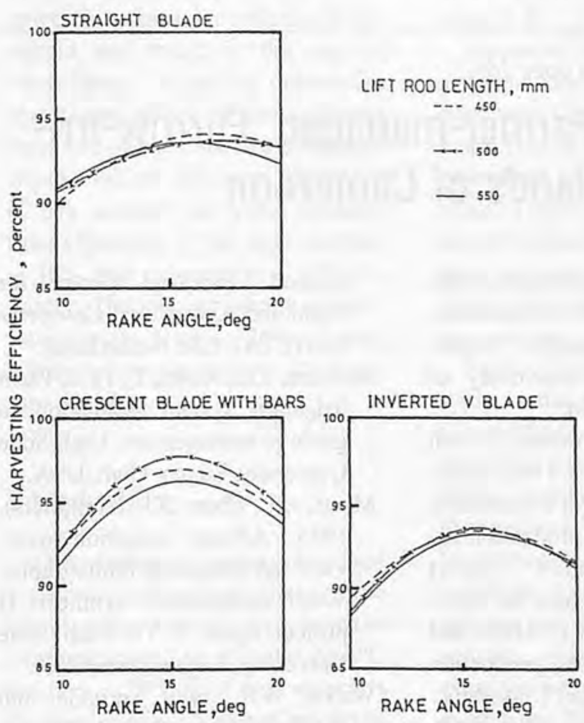

Fig. 3 Effect of rake angle on harvesting efficiency with different blade types.

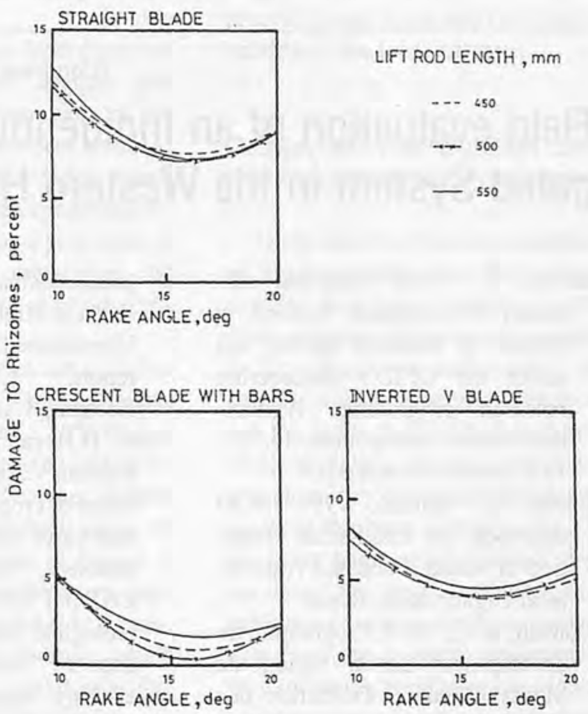

Fig. 4 Effect of rake angle on damage to rhizomes with different blade types.

Table 1. Field Performance of Power Tiller Operated Turmeric Harvester (Mean Values of Three Replications)

Variety	Soil type	Soil moisture percent	Spacing cm	Harvest. efficiency percent	Effective field capacity ha ha/h	Damage percent	Field efficiency percent	Cost of operation Rs ha/h
Erode	Clay loam	14.72	45 × 20	98.21	0.049	0.92	72.17	1540.04
Salem	Clay loam	13.38	45 × 20	97.96	0.052	1.04	77.56	1442.30
BSR-1	Sandy loam	9.34	60 × 20	98.57	0.057	0.81	84.16	1315.78
	Mean			98.24	0.053	0.92	77.96	1432.70

Based on the analysis of the investigation, the following conclussions are drawn:

1. For achieving maximum harvesting efficiency and minimum damage of a power tiller operated turmeric harvester, the optimized design parameters are crescent shaped blade with rake angle of 15 deg and lift rod length 0f 500 mm.
2. Harvesting turmeric rhizomes with power tiller-operated harvester is highly economical as about 63.7 percent savings in cost and 91 percent savings in time was achieved when compared to manual digging.
3. The extent of damage caused to the rhizomes is very much less (0.92 percent) in harvesting with the power tiller harvester as compared to 4.52 percent observed in the case of manual harvesting.
4. The undug rhizomes left in the field was minimum (1.76 percent) when compared to a maximum of 6.43 percent in the case of manual harvesting.

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(Continued from page 28)

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Performance of an Indirect Solar Food Dryer in the Northern Iraqi Climate

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Abstract

An indirect solar food drier of the cabinet type employing a corrugated plate flat solar collector is designed and tested in the city of Mosul,Iraq. The testing indicated a significant effect of the collector flow rate on the collector efficiency which varied between 49.7% to 62.6% around the year. Summer time efficiency of the drier reached ~ 35% and dropped to ~ 30% in winter. The system helped concentrate tomato juice to 25% of total solids and potato slices to 7% moisture content.

Introduction

Dehydration of prouce for food consumes a significant share of the world energy expenditure, where the evaporation of 1 kg of water at 63°C requires ~ 2500 kj of heat and calls for the use of ~ 62.9 kg of dry air to carry the water vapor if the air is to be fully saturated [5]. The addition of overhead energy requirements for transportation, harvesting, etc, raises the energy consumption in food processing to 12% of the national energy consumption in the USA [7]. However, since most of the energy required for food dehydration and processing is at temperatures lower than 80°C, researchers assessed that up to 50% of such energy can be supplied by low technology solar systems [3,4].

A number of solar food dryers of different conceptual designs had been tested in different parts of the world [5,6,7]. On the local level, Al - Shaibani and Hameed, [1], tested a mixed type solar dryer and reported a 65% decrease in drying time of food products as compared to the direct normally used methods during summer.

Sabbah [12], carried out a similar study in the Saudi Arabian Desert climate and reported a 50% drying efficiency for the tracking system he tested. Similar to the other middle East regions, the northern sector of Iraq down to the city of Mosul is noted for its high agricultural production and the availability of reasonable solar insolation which averages between ~ 2450 w/m^{2}day in June to 1700 w/m^{2}day in December. However, reviewing the available literature indicated the lack of a systematic study of the use of solar food dryers in the area. The present paper outlines the thermal results obtained from the experimental work which included the design and testing of an indirect solar food dryer of the cabinet type in the city of Mosul during both winter and summer seasons. Such results are intended besides other things, to serve as a validation data for already present design tools and their applicability to the local climates.

Design of the System and the Experimental Procedure

There are two possible methods of implementing solar food dehydration, direct and indirect. In the direct method products are exposed to the direct sun and natural air streams. Contamination of the food and the adverse effects of the ultraviolet radiation on the food color and chemistry are among the drawbacks of this type of dryers, [8]. On the other hand, using indirect dryers where the food is enclosed in a cabinet and air is used to convey heat from the collector and carry a way moisture, the above mentioned problems are partially or completely solved at the expense of some reduction in the system efficiency. Further more, the separation of food compartment from the collector allows easy control of temperature and air flow rate, heat storage and the application of auxiliary heat when necessary [11,12].

For the reasons discussed above,

an indirect cabinet type dryer is chosen for this study. **Figure 1** shows a schematic diagram of the system, which consist of a 60 degrees corrugated plate solar collector and a cabinet.

The collector is 0.8 m wide and 1.74 m long with 12 triangular air channels. The corrugation increases the surface area for solar absorption and convection heat transfer, hence increases the collector thermal efficiency by 9-15% over plain flat plate collectors [13,14]. The plate is coated with dull black paint (s = 0.87) and covered with a single 4 mm glass cover at 0.03 m crest to glass gap distance. The collector back is insulated with 0.1 m glass wool (k = 0.034 w/m^2 °C). The dryer cabinet is a 1.15 × 0.53 × 0.67 m insulated box with four 0.43 × 0.8 m shelves. Air is drawn through the system via proper ducts and a 100-watt variable speed fan. The cabinet and air ducts are insulated with a five-centimeter glass wool as well.

The adopted measurement system consisted of 22 type k (Nickle)(Chrom-Nickle) thermocouples distributed over the important points of the system to measure surface, product, and dry and wet bulb air temperatures. Airflow rate is measured using a specially designed and calibrated venturi-meter. Finally, solar insolation on the collector plain is measured using a "solar 118" Pyranometer capable of producing instantaneous and integrated solar radiation values.

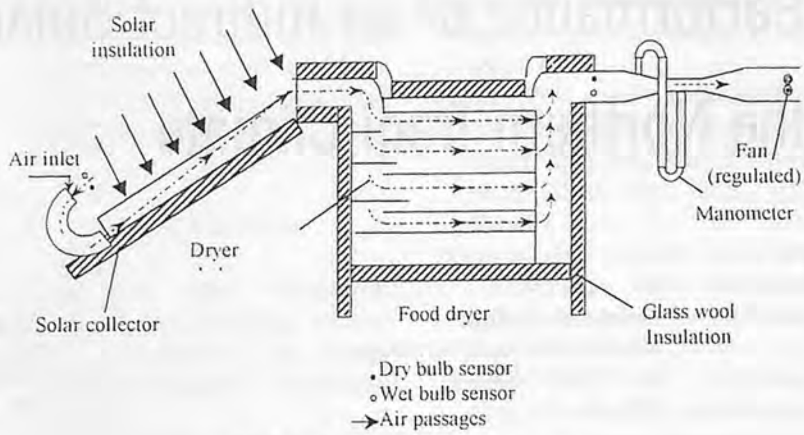

Fig. 1 Schematic diagram of the solar.

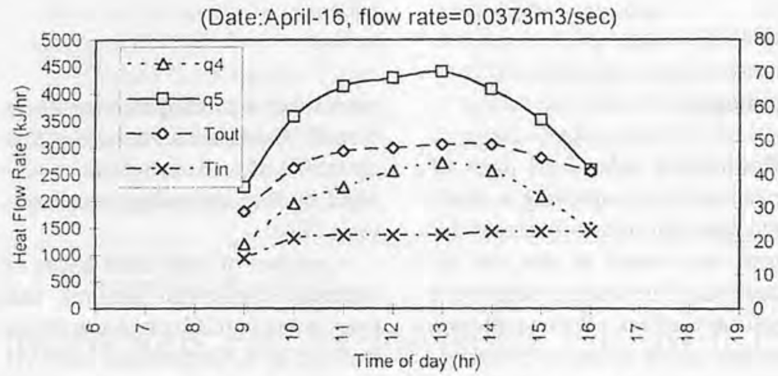

Fig. 2 Collector performance during a spring day.

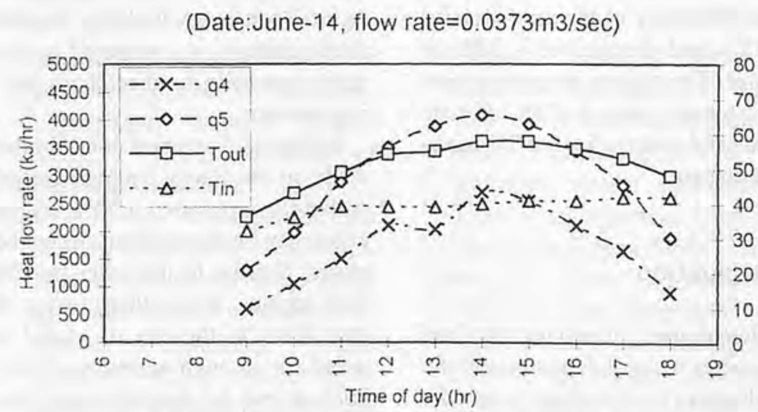

Fig. 3 Collector performance during the month of June.

Result and Discussion

Figures 2 to **5** shows the variation in the performance indicators (I, qu, Tin, Tout) of the collector over three different seasons at a constant air flow rate of 0.0373 m^3/s. The results shows that the useful energy delivered by the collector follows closely the variation of the incident radiation with a maximum qu and Tout occurring at the interval of maximum solar radiation. The collector outlet temperature varied between 40°C and 60°C over seasons. **Figures 8** to **11** shows that the efficiency of the collector follows the variation in Tp, the plate temperature, and is minimally affected by the season. These results supports the conclusion reported by Parker et al., [9] , who stated that the air flow rate per unit collector area is the factor of major effect on the collection efficiency. **Figures 9, 12** and **13** shows c for three climatically close days of June with the collector running at flow rates of 0.0328, 0.0373 and 0.0434 m^3/s. These figures show a clear dependence of the collector performance on the air flow rate where the averaged qu and c measured (1.54 MJ/day, 49.7%), (1.7

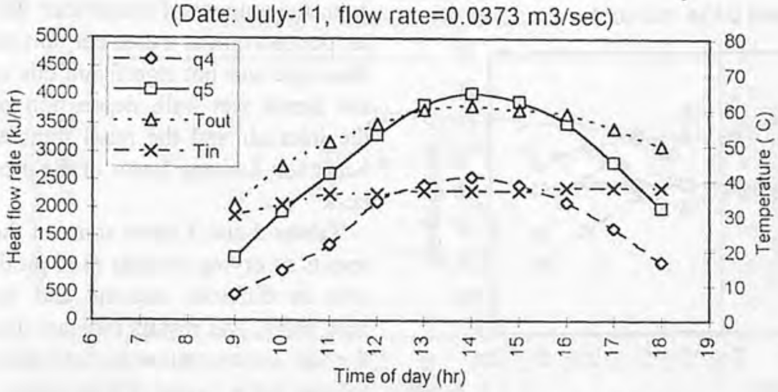

Fig. 4 Collector performance during the month of July.

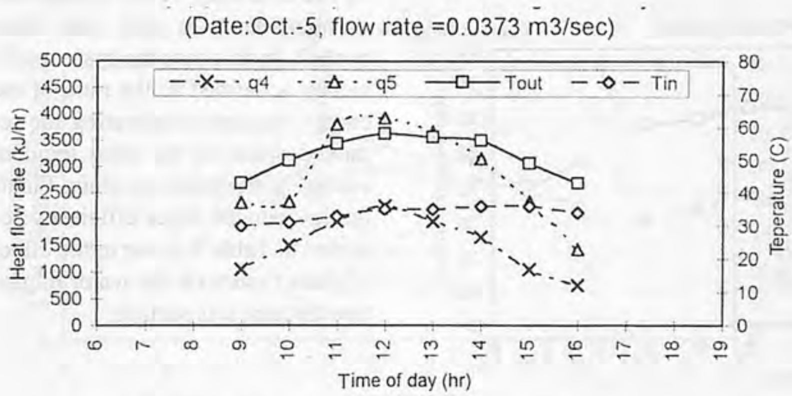

Fig. 5 Collector performance during a fall day.

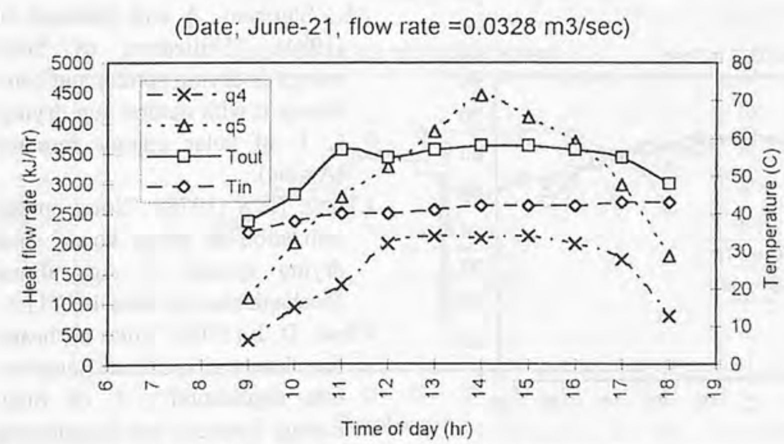

Fig. 6 Collector performance during a summer day.

Table 1. Solar Collector Heat Losses over Studied Months

Month	Averaged heat loss	Averaged heat loss coefficient w/m^2 C	Averaged wind speed m/sec.
Sept.	144	5.80	0.60
Oct.	196	6.05	0.89
Nov.	180	5.95	1.00
Feb.	244	5.75	0.85
Mar.	265	5.45	0.90
Apr.	170	5.25	0.50
May	127	5.60	on 1.30
Jun.	138	6.05	1.05
Jul.	145	6.10	1.80

MJ/day , 56.4%) and (1.88 MJ/day, 62.6%) for each of the flow rates, respectively. Those numbers indicate an almost linear effect of the mass flow rate on c where a 14% and 30% increases in the flow rate caused a 13% and 26% increases in c, respectively. These results are reasonably close to those reported by Close [3] and are due to the improved heat removal factor of the collector and the relative reduction in Tp hence the collector losses at the higher flow rates. **Table 1** lists the minimum and maximum values of U_L, the overall heat loss factor, over the different months of the year. The variation in the estimated values of U_L are relatively small and may be considered within the measurements error effects which supports the constant U_L value assumption usually suggested in the collector design procedures.

To overcome the effect of different food surfaces on the dehumidification efficiency, the system is tested using free water in the pans of the dryer. **Figures 14** and **15** show the performance of the system over two days with close daily solar insolation using two different air flow rates (0.0328 and 0.00434 m^3/sec). The evaporation efficiency is calculated as the actual to the maximum possible vapor absorption by the air going through the dryer.

It is obvious that increasing the air flow rate increases the amount of evaporated water. However the humidifying efficiency of the air decreases with flow rate due to the reduction in the humidifying time of the air, i.e., the dehumidifying capacity of the dryer increases with the air flow rate although the saturation ratio of the air decreases which indicates the possibility of further increasing the evaporation capacity through increasing the contact area or length of air passage through the dryer. On the two test days the drier was capable of removing ~ 5 (kg/m^{2}day) of water for the high flow rate versus ~ 4(kg m^2 day) for the low air flow rate. How-

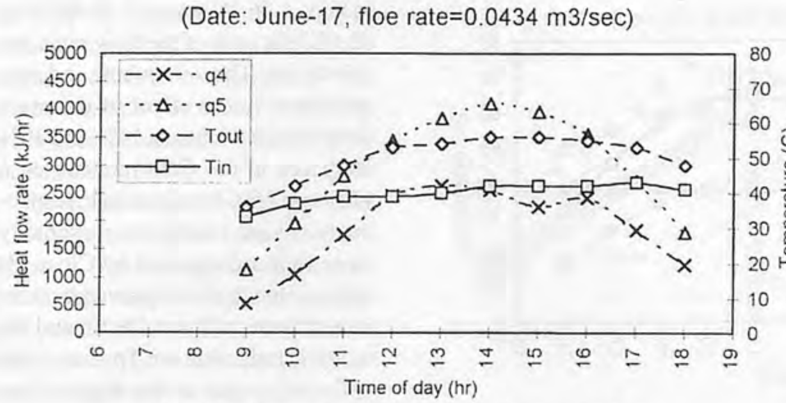

Fig. 7 Collector performance during a summer day.

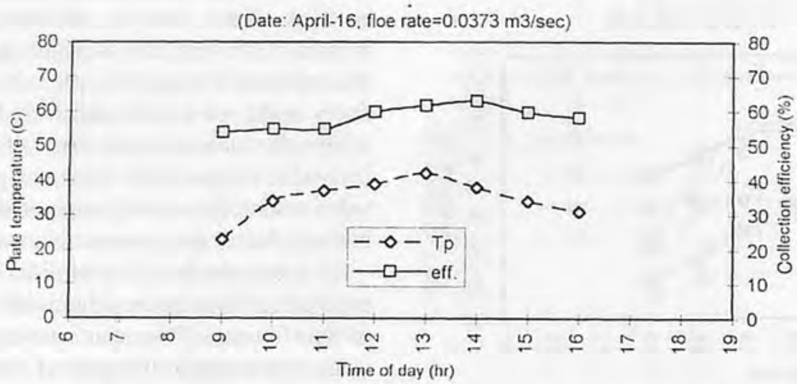

Fig. 8 Variation of collector plate temperature and collection efficiency during a spring day.

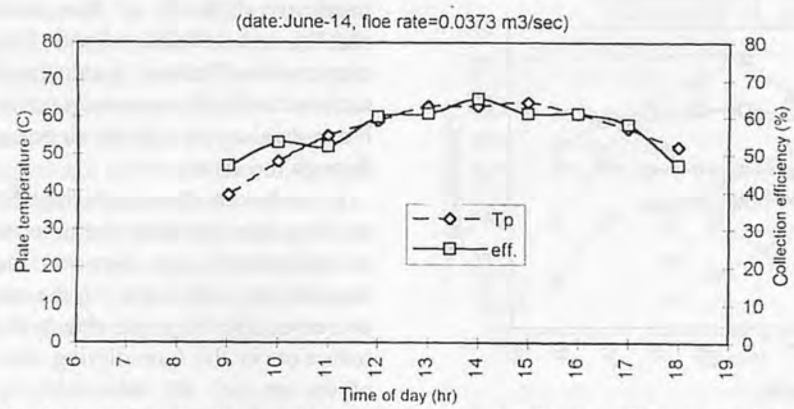

Fig. 9 Variation of collector plate temperature and collection efficiency during a summer day.

Table 2. Tomato Juice Concentration Results

Item	Flow rate	$0.0328\ m^3/sec.$	$0.0434\ m^3/sec$
	2/7	14/10	6/7
Daily total radiation MJ/day	30.8	21.6	27.9
Daily useful energy MJ/day	15.4	9.8	20.1
Evaporated water quality (kg)	7.8	3.1	8.1
Drying period (hr)	10	7	10
Collector efficiency %	46.2	45.7	54.5
Average drier efficiency %	33.9	31.4	34.1
Average system efficiency %	15.7	14.3	18.6
Final juice concentration %	18	14	25

ever, the amount of evaporated water per pan unit and area per unit air flow rate was not significant due to the larger wet bulb depression of the inlet air and the mass transfer being the limiting factor in the process.

Tables 2 and **3** show some of the results of drying various food products in different seasons and air flow rates. The results indicate that the low concentration tomato juice follows the behavior of free water.

Again, the effect of air flow rate on the efficiency of the system and its components is very clear from **table 2.** In this case the system efficiency is defined as the ratio of the energy required evaporating the removed water to the total incident energy on the collector plain. Finally, the reduced dryer efficiency reported in **Table 3** is due to the effect of plant tissues on the water migration through it is surface.

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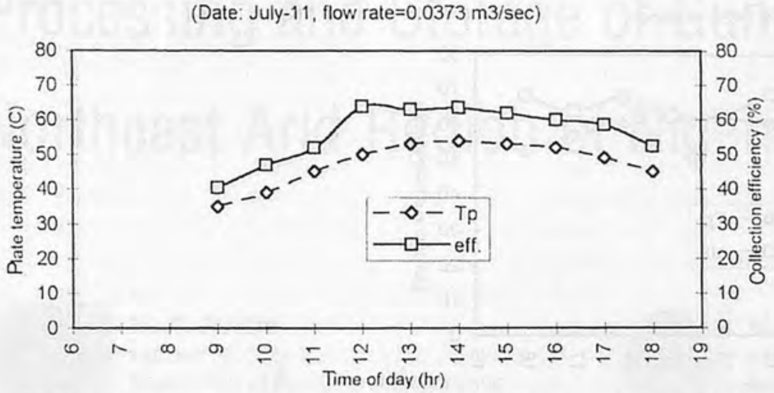

Fig. 10 Variation of collector plate temperature and collection efficiency during a summer day.

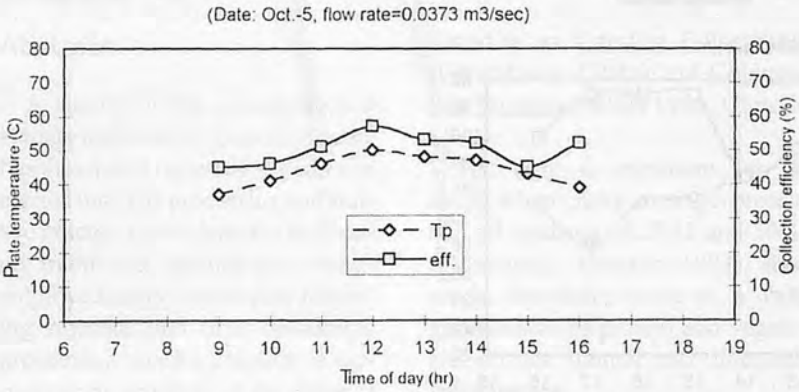

Fig. 11 Variation of collector plate temperature and collection efficiency during a fall day.

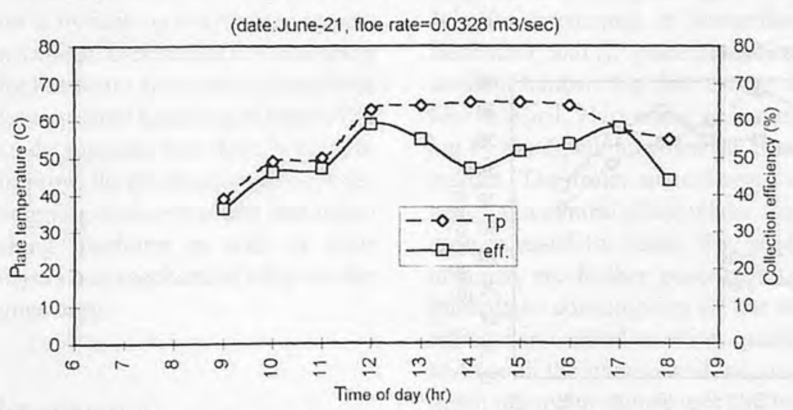

Fig. 12 Variation of collector plate temperature and collection efficiency during a summer day.

Table 3. Varying produce concentration results

Percent moisture	Potato	Egg plant	Squash	Spinach	Celery
	81	91	90	91	91
Incident energy (MJ/day)	31.3	24.6	26.2	26.6	25.5
Useful energy (MJ/day)	15.8	16.3	11.0	10.9	11.5
Drying period (hr)	8	10	8	8	8
Final moisture %	10	6	16	35	30
Removed water (kg)	3.9	6.0	2.9	1.8	1.9
Drier efficiency %	22	20	22	21	22
Air flow rate m^3/sec	0.0373	0.0434	0.0226	0.0226	0.0226
Drying month	May	Jul.	Apr.	Feb.	Mar.

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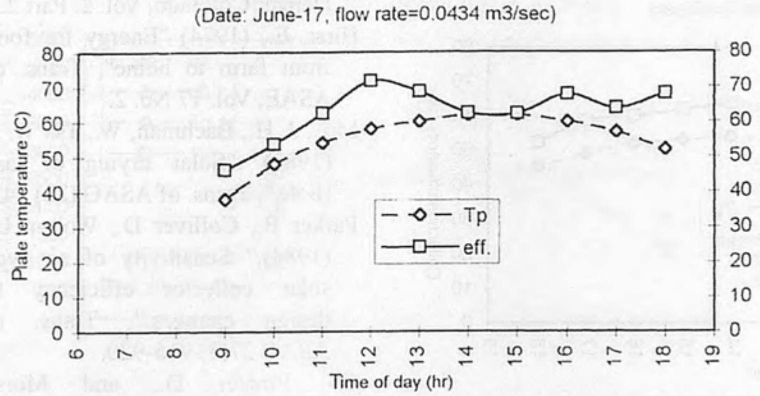

Fig. 13 Variation of collector plate temperature and collection efficiency during a summer day.

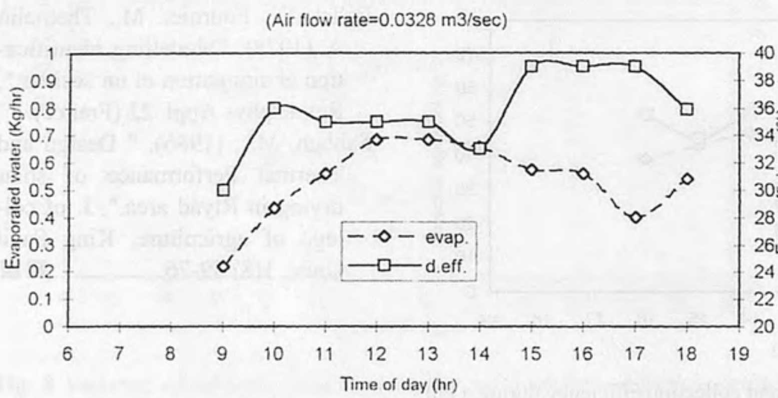

Fig. 14 Drier performance at low air flow rate.

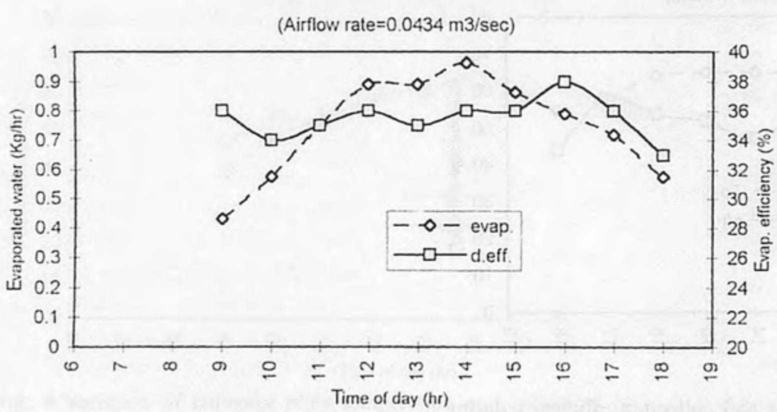

Fig. 15 Drier performance at high air flow rate.

Processing and Storage of Guna Crop in the Northeast Arid Region of Nigeria


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Abstract

A survey of the processing and storage methods for guna crop in the Northeast arid region of Nigeria was carried out. The processing and storage practices were found to be based on traditional technologies which employed crude techniques involving rigorous and time consuming procedures. Seed extraction is carried out by crushing or decaying of guna fruits while dehusking of seeds is done either by pounding in a mortar or by striking in a jute bag against a wall. Oil is extracted from the seeds by hot water flotation or traditional low pressure kneading of paste. The study suggests that there is need to improve the existing practices by developing seed extracting and dehusking machines as well as solar dryers and mechanical oil press for guna crop.

Introduction

The guna crop is a drought tolerant crop of the cucurbitaceae family,(**Fig. 1**) which is grown in the Northeast arid region of Nigeria, particularly in Yobe State. The Hausa name 'Guna' by which the crop is known has been used because its botanical taxonomy is still lacking a conclusive agreement. It is generally considered to be of the Citrullus species and has been referred to as Citrullus Colocynthis (Gwandzang 1994a) and Colocynthis Vulgaris (Willis 1966, Olorode 1984).

The crop is important for its seeds which have average protein and oil contents of 27.13 and 50%, respectively, (Norton 1993). The seeds, therefore, serve as a very good source of protein and vegetable oil for human and livestock consumption.

Two cropping periods are practiced annually: (1) planting in June/July for harvesting in November/December, and (2) planting in September/October for harvesting in March/April. Harvesting is carried out by hand picking when the fruits mature. The fruits are collected in heaps at a central place where they are processed for seeds. The seeds obtained are further processed for immediate consumption or for oil which has a good cooking quality and use in the pharmaceutical, cosmetic and paint industries. The nutritional and economic importance of the crop and its seeds have generated the need for improvement of its processing and storage practices in order to ensure the availability of the product all year round.

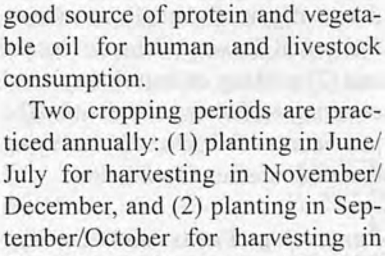

Fig. 1 Guna crop in the field.

This paper presents the findings of a survey on the processing and storage practices of guna crop and the problem associated with them. The appropriate measures needed in improving these existing practices, are examined and recommended.

Methodology

For the purpose of the survey, Yobe State was chosen because guna crop production in the Northeast arid region is concentrated in it. The State was divided into three zone (**Fig. 2**), as follows: (1) Southern comprises Gujba, Fika and Nangere local government areas, where the crop is not produced. For this reason, the survey was not conducted in this zone; (2) Central covers Jakusko, Fune and

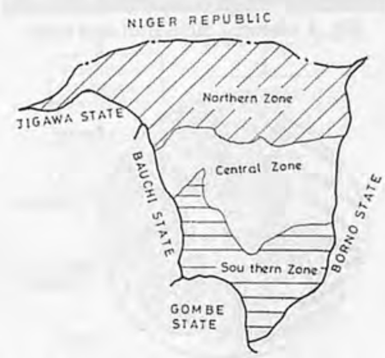

Fig. 2 Map of Yobe state showing the three zones.

Damaturu local government areas; and (3) Northern comprises Machina, Nguru, Yusufari, Yunusari, Geidam, Bursari, and Bade local government areas.

The survey was carried out with the use of questionnaires, field trips and interviews with farmers. Five villages from the Central zone were randomly selected to reflect the fadama area, while 15 villages were selected from the Northern zone to represent the semi-arid and arid areas where guna production is mainly concentrated. The operations carried out by 10 farmers in each village were closely monitored for a period of 13 months which covered the time of planting, harvesting, handling, storage and processing activities.

Results and Discussion

The information obtained from the survey are discussed below.

Guna Seed Extraction

The seeds are extracted from matured guna fruits (**Fig. 3**). The fruit is spherical in shape and when matured, it has an appropriate average major and minor diameters of 8 cm and 6 cm, respectively. It is usually dark green in colour during growth and pale yellow or milky when matured and ready for harvesting. It consists of a tough outer covering (epicarp) and a hard inner layer (mesocarp) of about 1 mm and 9mm thickness, respectively. These enclose a pulpy endocarp in which the seeds are embedded. The seeds are held in peripheral compartments at a density which increases from the centre towards the outer wall (**Fig. 4**).

Fig. 3 Matured guna fruit and seed.

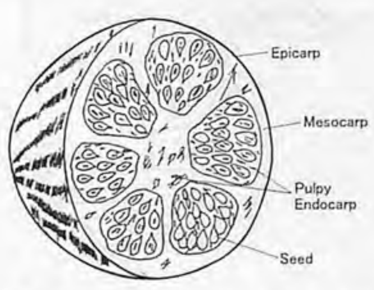

Fig. 4 Cross-section of guna fruit snowing seed arrangement.

There are two methods of extracting guna seeds from the fruits: (1) by manual crushing of fruits with a pestle, and (2) by decaying the fruits. The farmers pointed out that the first method was energy sapping and time-consuming. As a result, they resort to the second method which lessens the rigours involved in breaking the pods. The farmers use two ways to achieve the decay of guna fruits: (1) puncturing fruits and leaving them in heaps, and (2) packing of fruits into pit and covering with leaves and soil. The procedures followed in carrying these out are described below.

Puncturing Fruits and Leaving Them in Heaps

In this approach, the fruits are punctured manually at several points with a metal rod and collected in heaps. They are then covered with grass or leaves and left to decay. In some cases, the heaps are left without any form of covering and, depending on the ambient temperature and humidity, the decaying process takes about two to three weeks. According to Gwandzang (1994b), an acrid or pungent smell usually develops when the fruits decay. This approach is mainly practiced in the Central zone and fadama areas.

Packing of Fruits into Pit and Covering with Leaves and Soil

This involves digging a pit into the soil and lining it with polythene materials or leaves and grass. The fruits are then packed into it without punctures and they are covered with leaves and soil. The set up is left undisturbed for a period of one to two weeks during which the fruits decay. After this period, the pit is uncovered and the fruits removed. This approach is mainly practiced in the Northern drier zone.

The decay process having weakened the epicarp and mesocarp of the fruits, enables them to be easily broken by hand. The pulp and seeds are scooped out of the pods as shown in **Fig. 5**. Seed extraction from the pulp then commences from this point.

Fig. 5 Scooping of pulp and seeds from decayed fruits.

Separation of Seeds from Pulp

Two methods of extracting seeds from the pulpy mass of endocarp are employed. In the first, the seeds are separated from the liquid and solid constituents of the pulp by pouring the bulk material into a riddle fitted with screen, and washing it several times with water until clean seeds are obtained (**Fig. 6**). The riddle is made of a wooden topless box with a bottom consisting of a screen formed from perforated metal sheet. The improved version has wooden stands with which it is raised from the ground. When the riddle is used to separate the seeds from decayed fruit pulp, the liquid component and mucilage of the pulp get discharged through the perforations at the base and the seeds are retained. They are collected and sun-dried by spreading on a mat or hard flat surface in an open space. The clean seeds obtained from this method are said to command high market values.

The second method involves pouring of the scooped pulp and its contents on a clean hard surface where it is sun-dried for at least two days. After this, caked up material consisting of seeds and dry mucilage is obtained (**Fig. 7**). This material is spread on a mat and beaten with stick to loosen the seeds from the dry mucilage. The dry and caked mucilage is broken into small particles during this operation and the seeds are separated by winnowing. Seeds obtained this way are not usually as clean as the ones from the first, and as a result, they normally have reduced market value. However, farmers prefer this method as it does not require the use of water which is very scarce in the area. The intensity of solar radiation in the area is also high and this enables the drying of scooped pulp to be achieved without much cost. The second method was found to be less labour intensive. Winnowing operation is aided by the high wind velocities obtaining in the area. The by-products of seed extraction are packaged for use as animal feed, or in some cases, they are left to decay on farm land and add humus to the soil. The flow chart of guna seed extraction is shown in **Fig. 8**.

Problems Associated with Seed Extraction

The following are the observed problems of guna seed extraction using the current practices:

1) The extraction of seeds by impact breakage of fruits using pestle is energy sapping.
2) Fruit puncturing exercise is time-consuming, tiresome and hazardous.
3) The time taken to decay the fruits and scoop out the pulp containing seeds is long. Also, losses occur in the process of retrieving the fruits from the pit. The fruits piled up in heaps to decay for seed extraction are usually attacked by pests, rodents and farm animals.
4) The process of washing the pulp to obtain clean seeds requires plenty of water which is not readily available in the region. This process was also noted as being tedious and time-consuming with the occurrence of losses.
5) The method of sun-drying the scooped pulp results in overdrying of the seed. This leads to breakage during impact separation from the caked mucilage. The separation operation is energy sapping and the force applied also damages the seeds.
6) Appreciable losses of seeds occur during winnowing.

Primary Processing of Guna Seeds

Guna seeds are small, flat and oval in shape (**Fig. 3**). They are dicots and consist of yellowish outer husk (seed coat) and milky cotyledon (endosperm). The primary processing operation involves the dehusking of seeds to obtain cotyledons for use in oil extraction or soup preparation.

Fig. 6 Seed separation from pulp using local riddle.

Fig. 7 Dry and caked guna mucilage containing seeds.

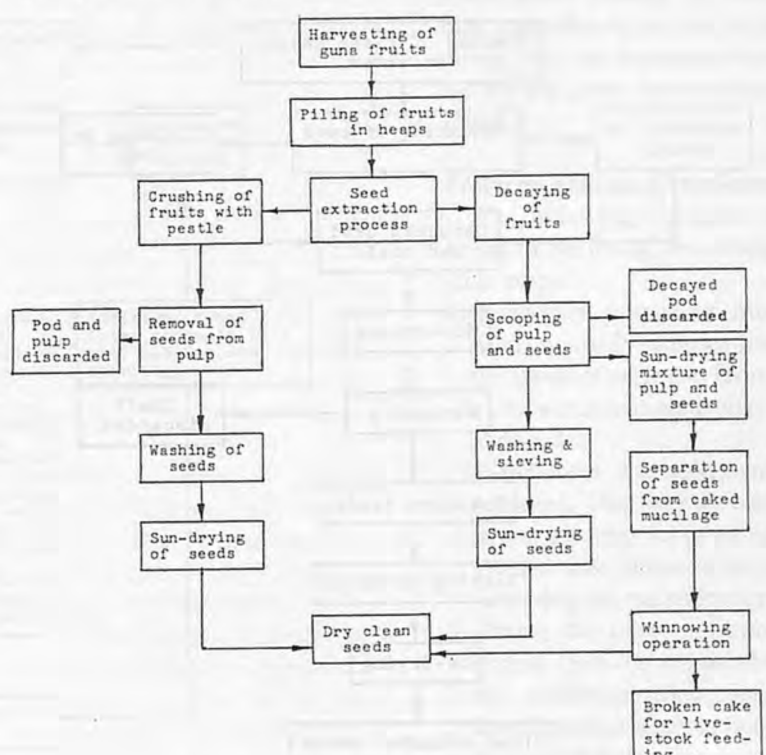

Fig. 8 Flow chart of guna seed extraction.

Methods of Dehusking the Seeds

The clean seeds are soaked in a container with water for one to one and a half hours to enable the husk to expand away from the cotyledons. They are then removed, dried, poured into a mortar and dehusked by pounding gently with a wooden pestle. After this, the mixture of cotyledons and husks are spread on mats and sun-dried for four to five hours. They are, thereafter, separated by winnowing. The dehusked seeds are thoroughly washed and re-dried to obtain clean product. Dehusking is also achieved by pouring the seeds into a jute bag and striking the bag against the wall of a building. The by-products of seed dehusking operation are used as animal feed The flow chart of guna seed primary processing is shown in **Fig. 9**. Single-seed hand shelling process is not practiced due to the seed size. Odigboh (1979) reported this practice for egusi melon which belongs to the same family as guna but larger in size. He, however, noted that the operation is tedious and time-consuming.

Problems Associated with the Primary Processing

The dehusking operation has the following problems:

1) Dehusking of seeds by pounding in a mortar or striking in a jute bag, not only contaminates but also damages the product. This leads to reduction in market value. Also, these methods can only handle small quantity of crops.
2) Dehusked and broken, undehusked, partially dehusked and undehusked but broken seeds are obtained in appreciable quantity from these methods showing them to be quite inefficient.
3) The rate of drying of seeds cannot be controlled and this usually leads to over-drying with the consequent increase in dehusking losses. The seeds are also exposed to the attack of birds, insects and to contamination by dust during drying.

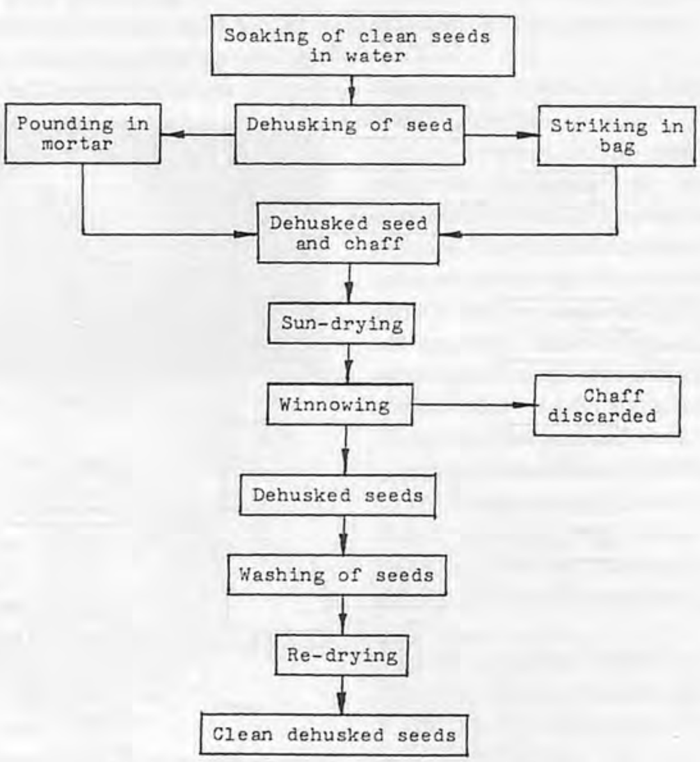

Fig. 9 Flow chart of primary processing of guna seeds.

Secondary Processing of Guna Seeds

The secondary processing operation involves oil extraction from dehusked seeds and preparation of by-products for human and livestock consumption.

Methods of Oil Extraction

Two methods are employed in extracting oil from guna seeds: (1) The hot water flotation, and (2) the traditional low pressure. The hot water flotation method is, however, found to be more popular. In this method, the dehusked seeds may or may not be given mild roasting in a metal pan heated over an open fire. The farmers explained that the roasting treatment usually quickens oil extraction and introduce an attractive colour to the oil. It is possible that during roasting, the seed pores expand and open up, thereby making the material more permeable and the oil constituent more fluid. The seeds are then ground into paste using a grinding stone or pestle and mortar. The paste is scooped into a metal pot containing hot water and the pot is mounted on a tripod and heated with fire. The content is stirred continuously until oil oozes out of the paste-hot water mixture and floats on the surface (**Fig. 10**). When an appreciable quantity of oil has accumulated, a ladle is used to collect it into a container. Stirring of the paste is continued with occasional collection of oil until the flow stops. Some times the oil is heated to evaporate the water it contains before it is bottled

Fig. 10 Hot water flotation method of guna oil extraction.

for consumption or sale. The remaining component of seed paste is treated with salt, rolled into balls and re-fried in oil. These balls are sold for human and livestock consumption as guna cake known locally as "Kwuli-kwuli". If undehusked, the seeds are used for oil extraction, the by-products are not processed for human consumption but used as livestock feed. The traditional low pressure method differs from the hot water flotation method only by the fact that smaller amount of water is added to the paste and it is kneaded to press out the oil. The flow chart of secondary processing of guna seeds is shown in **Fig. 11**.

Problems Associated with the Secondary Processing

The following problems were identified with the secondary processing of guna seeds:

1) The extracted oil usually contains a lot of moisture and residues which affect its quality and storability.
2) The oil extraction is manual and this makes it tedious and time-consuming.
3) The person carrying out the oil extraction operation is exposed to excessive heat.
4) A large percentage of the oil contained in the seeds is left unextracted as can be seen from the fat content of the cake which, according to FIIRO (1984), is about 31%. This shows that the extraction efficiencies of the present methods are very low.

Guna Fruit and Seed Storage

The survey revealed that the guna fruit itself is not stored for a long period as it is rarely utilized. Guna crop production is mainly aimed at obtaining the seeds which are always immediately extracted from fruits after harvesting. Prior to seed extraction, the fruits are stored at the farm in heaps or in pits to enable them to decay. At the farm level, the seeds are stored in baskets and gourds. If the seeds are to be preserved for planting, the baskets are covered with dry leaves and the gourds are sealed. They are placed on platforms in a dry environment under shed.

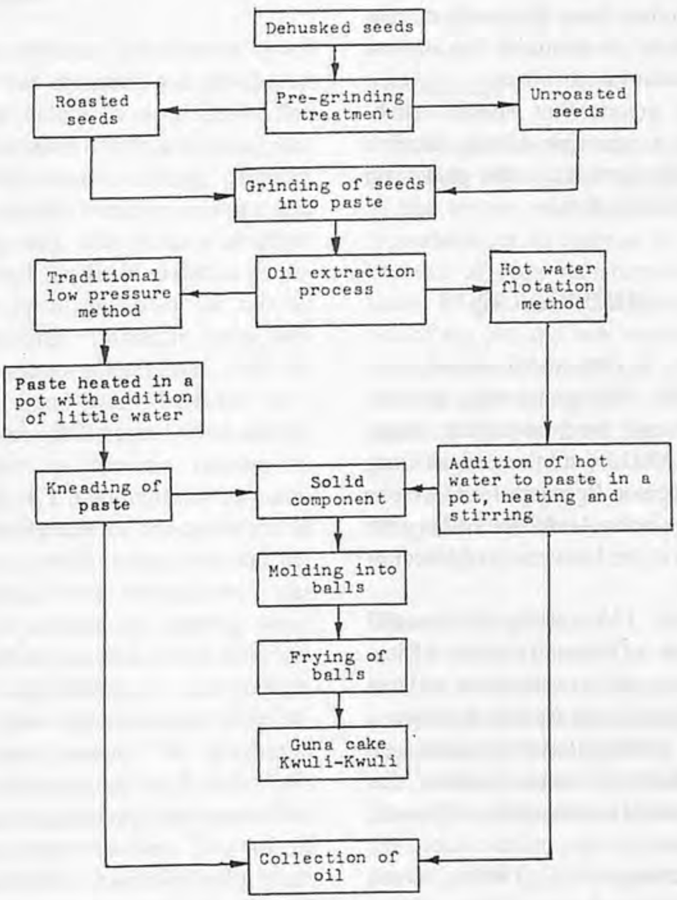

Fig. 11 Flow chart of secondary processing of guna seeds.

Commercial Storage

At the commercial level, guna seeds are stored either in dehusked or undehusked conditions in jute, hessian or plastic bags stacked on warehouse floors by wholesale business-men. In some warehouses, platforms are used to raise the product up from the floor. These warehouses are located at the main outlet of the seeds which is the Nguru market. They are owned by individual businessmen or jointly by members of Guna Marketers' Association. Storage of seeds in bins and silos is yet to be introduced. Also, no government owned facility for guna crop storage was found.

Problems of Guna Crop Storage

The following problems were found to be facing the storage of guna crops:

1) Temporary storage of fruits in heaps normally exposes them to the attack of pests and farm animals which consume the fruits and seeds.
2) Warehouses are unhygienically managed. This leads to contamination by dirts, debris of materials and dust blown in by wind. Also, they are not rodent-proof.
3) During the rains, moisture migration from the ground through the warehouse floor into the stored product leads to fungal attack and deterioration.
4) Storage of seeds in bags stacked

on each other on warehouse floors or platforms does not provide for adequate aeration and this can result in the emission of unpleasant odour during long storage and lead to aflatoxin development.

Conclusion and Recommendations

The processing and storage of guna crop in the Northeast arid region of Nigeria are based on traditional technologies which employ crude techniques involving rigorous and time-consuming procedures. There is, therefore, need to improve these practices and employ new methods based on the following recommendations:

1) A mechanical device for the purpose of extracting the seeds from fruits should be developed based on the engineering properties of guna fruits and seeds.
2) A mechanically-operated guna seed dehusker should be developed to replace the manual methods presently employed. The Yobe State Agricultural Development Project (YOSADP) attempted an adaptation of the impact egusi shelling machine developed at the Department of Agricultural Engineering, University of Nigeria, Nsukka, to the dehusking of guna seeds. Adequate modification can be made on the machine to make it suitable for guna seeds.
3) Solar dryers using natural convection should be introduced into the crop producing area. This will replace the sun-drying method being practiced and offset the short-comings.
4) More efficient and refined methods of oil extraction should be introduced. This can be in form of either a mechanical press or organic solvent.
5) Cottage industries producing cosmetic and pharmaceutical products from guna oil should be established in the area.
6) Seed storage in improved structures such as the Rhumbu should replace the basket and gourd storage. Fruit storage in cribs should be evaluated and research work on guna crop storage should be encouraged by the government.
7) Warehouses for seed storage should be made water tight and leak proof. Also, they should be made rodent proof and well fumigated. They should receive as little solar radiation as possible. This can be achieved by constructing the buildings in such a way as to enable the longer axis to run East-West, because, according to Igbeka (1983), more solar radiation falls on the East and West walls than on those of the North and South, in Nigeria. The East and West walls should, therefore, have the smallest areas in order to minimize the amount of radiation absorbed.
8) The government should establish a strategic Grain Reserve (SGR) complex in the guna crop producing area.

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Design and Development of Osmotic Dehydration Pilot Plant for the Dehydration of Fruits

by

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Abstract

An osmotic dehydration pilot plant was designed and developed for the dehydration of fruits. The plant consists of a fruit holding pan, osmotic reactor, mixing chamber with heater, pumping system and drying unit. The mixing chamber was used for the preparation of osmotic syrup and also for mixing and heating of osmotic syrup during osmotic dehydration. The osmotic syrup was circulated at a flow rate of 12 l min^{-1} from mixing chamber to osmotic reactor by means of a pumping unit to maintain uniformity of concentration of osmotic syrup during osmotic dehydration. The drying unit was used to remove the existing water content in the fruit slices after osmotic dehydration for safe storage. This plant was evaluated using banana and papaya. The maximum water removal of 42.5 and 60.08 percent respectively for banana and papaya were observed. The cost of the osmotic dehydration pilot plant along with drier was Rs. 70,000 (US$ 1600). The cost of operation per hour was Rs. 65 (US$ 1.5).

Introduction

Fruits are seasonal crops and perishable in nature. The perishability is due to the microbial load and characteristics of storage of fruits because of high moisture content above 80 per cent. Dehydration is one of the old and best methods of preservation of fruits and vegetables. Of all the available dehydration technique, osmotic dehydration gives high quality product with less cost. Freeze-drying gives high quality product but the cost of production is high.

Osmotic Dehydration

Osmotic dehydration is the process of water removal from water containing cellular solid (fruits and vegetables) by immersion in a concentrated aqueous solution. The driving force for water removal is the concentration gradient between the solution (high concentration) and the intracellular fluid (low concentration). This will directly affect the water activity and produce a completely new environment that may prevent microbial growth or chemical reactions from occurring. The main advantage of osmotic dehydration is that it minimises the damage to the cellular tissue and removes water without phase change. The osmotic dehydration as a method of partial dehydration of fruits by osmosis in sugar syrup has been investigated by Ponting *et al.* (1966). In this process the fruit weight was reduced to about 50 percent of its original weight by osmosis after which the fruit was frozen or air-or vacuum-dried. The factors affecting osmotic dehydration are pre-treatment, temperature, nature and concentration of osmotic solution, agitation or circulation on the mass transfer and on the product quality have been reviewed by Ponting *et al.* (1966), Bongirwar and Sreenivasan (1977), Hawkes and Flink (1978), Lerici *et al.* (1986), Ravindran (1987), Rahman and Lamb (1990), Sharma *et al.* (1991) and Ahmed and Choudhary (1995). Lazarides *et al.* (1995) applied thorough and gentle agitation of the osmotic medium using a mechanical stirrer at 150 rpm. The agitation was given to improve mass transfer and prevent the formation of a dilute solution film around the samples.

Garcia *et al.* (1974) studied the osmotic dehydration of fruits like banana, papaya and pineapple in pilot plant scale. The plant consists of 100 litre SS tank, SS centrifugal recirculation pump, electric heater, automatic temperature control and hot air drier. Yang and Maguer (1992), constructed an osmotic dehydration apparatus consisting of an osmotic reactor made up of glass 20 cm inside diameter and 34 cm height. A 30 litre tank was used for the osmotic solution. The solution was circulated using a pump at the rate of 15 *l* min^{-1}.

Design

An osmotic dehydration pilot plant was designed and developed in the Department of Agricultural Processing, College of Agricultural Engineering, Tamil Nadu Agricultural University, Coimbatore, India for the dehydration of fruits. The plant consists of an osmotic reactor, mixing chamber, pumping system and drying unit. The design of the component of osmotic dehydration plant is as follows:

Osmotic Reactor

The osmotic reactor consisst of: (i) osmotic chamber, (ii) fruit holding pan; (iii) fruit pan holding mesh.

The fruit pan holding mesh along with fruit holding pan will be inserted into the osmotic chamber.

Fruit Holding Pan

The average bulk density of fruits taken for design was 600 kg m^{-3}. The capacity of pilot plant to be designed was 5 kg of fresh fruits per batch. The size of fruit holding pan was 270 mm diameter and 700 mm high. There are three fruit holding pan. These fruit holding pans were to be inserted into the fruit pan holding mesh. Perforations (10 mmϕ) were made in the fruit holding pan so that the syrup goes into the fruit slices. The fruit pan holding mesh contains three compartments. Each compartment has the size of fruit holding pan plus ten percent allowance. The height and diameter of each compartment were 95 mm and 320 mm, respectively.

Osmotic Chamber

The osmotic reactor consists of a stainless steel container in which fruit holding pan was to be placed along with fruit pan holding mesh. The gap between the holding mesh and osmotic reactor was 10 mm. The bottom clearance between the osmotic chamber and holding mesh was 30 mm. The diameter and height of osmotic chamber were 330 mm and 440 mm, respectively.

Mixing Chamber

The mixing chamber consists of a mixing container, impeller, heater and drive assembly. The volume of syrup needed for osmotic dehydration was 40 *l*. The volume of syrup staying in the mixing chamber for heating during osmotic dehydration was 12 *l*. The diameter and height of mixing chamber were 360 mm and 465 mm, respectively. The selection of impeller was made by inspection of viscosity and batch size. The impeller was for a viscosity of 70°B sucrose solution. Since the viscosity of 70°B sucrose solution was above 2000 centipoise (2 Nsm^{-2}) turbine type impeller was selected. The ratio of impeller diameter to tank diameter was 0.9 (Bates *et al.* 1966). Therefore, the diameter of the impeller was 325 mm. For thorough mixing, seven double impeller blades of length 150 mm each were attached to the impeller shaft at 50 mm in succession. For effective mixing without any hydraulic jump, an impeller speed of 50 rpm was optimised. The 50 rpm impeller speed was achieved by selecting different diameters of idler pulley impeller pulley and motor pulley using the formula.

$$N_1D_1 = N_2D_2$$

Where,
N_1 = Impeller speed
D_1 = Impeller pulley
D_2 = Motor pulley
N_2 = Motor speed

The power required for impeller rotation was calculated by determing the power number (N_p) and Reynold number (Re):

$$N_p = \frac{P}{\rho N^3 D_a^5}$$

Where,
P = Power, W
ρ = Density of solution, kg/m^3
N = Impeller speed, rps
D_a = Impeller diameter, m

$$Re = \frac{D_a^{\,2} NP}{\mu}$$

where μ - Viscosity, kg/ms

The power number was taken from the Bates curve by correlating the Reynold number with the number of impeller blade (Bates *et al.*, 1966). From the power number, the power required for rotating the impeller was calculated as approximately 0.5 hp.

Pumping System

The flow rate of syrup circulated in the process was optimised to be 12 *l* min^{-1}. The pump available in the market was only 25 *l* min^{-1}. Since 70°B sucrose syrup has specific gravity of 1.35, a positive displacement pump is very much suitable for pumping. A rotary gear pump of capacity (Q) 25 *l* min^{-1} was selected. The head (H) required for pumping is calculated as:

$$H = H_1 + H_2 + H_3$$

Where,
H_1 = Elevation difference between the pumping and discharge end.

H_2 = where f =

H_3 = Fitting loss (assumed = 0.2m)

Power (P_p) required for pumping sucrose solution was calculated as approximately 0.5 hp by:

$$P_p = \frac{\omega Q H}{75 \eta_p \eta_m}$$

ω = Unit weight of 70°B sucrose syrup

η_p = Pump efficiency

η_m = Motor efficiency

Selection of Air Dryer

After osmotic dehydration, the water content of fruits decreased from 400 kg H_2Okg^{-1} DM to 90 kg H_2Okg^{-1} DM. For further reduction of water content from 90 kg H_2Okg^{-1} DM to 20 kg H_2Okg^{-1} DM, the fruits were dried in an air drier. The air required for drying was calculated as 1.5 m^3min^{-1}. Assume 25% air loss, 2 m^3min^{-1} the capacity blower was selected.

Development

The framework for the pilot plant consisted of two parts. One part rectangular main frame and the other square frame. A rectangular frame of size 775 × 480 × 1225 mm was fabricated using 50 × 50 × 6 mm mild steel L angle to hold the osmotic reactor, motor, drive assembly and pump assembly. A square frame of 380 × 380 × 380 mm was fabricated with 40 × 40 × 6 mm mild steel L angle to hold the mixing chamber. The main frame and the square frame arrangements are shown in **Fig. 1**.

A hole of 20 mm diameter was drilled in the mixing chamber bottom at a distance of 70 mm from the outer circumference of the container and the outlet pipe was fixed with stainless steel flange and bolt and nuts. A similar arrangement was made at a distance of 50 mm from the top of the container to accommodate inlet pipe. Two numbers of heating elements (1500 kW) and a thermocouple were fixed to the container to heat the sugar syrup and to measure the temperature, respectively. The control panel with suitable thermostat controls was connected to maintain syrup temperature. The impeller was attached to the main frame with two ball bearings arrangement such that the impeller blades constantly dipped into the sugar solution enabling the mixing process. A 50-rpm impeller speed was achieved by selecting three pulleys, i.e., idler pulley, impeller pulley and motor pulley. The idller pulley has two diameter groves of 55 mm and 300 mm. The impeller pulley and motor pulley have a diameter of 300 mm and 55 mm, respectively.

A small platform of size 150 × 500 × 20 mm was made at the bottom of rectangular frame and a gear pump of capacity 25 l min^{-1} was attached. Six stainless steel ball valves were attached at different places as shown in **Fig.1** to run the process effectively.

Evaluation

The designed and developed osmotic dehydration pilot plant was tested using banana and papaya separately.

Fully matured banana and papaya were procured from local market, peeled manually and sliced using a stainless steel knife. The slice thickness of banana was taken as 10 mm and size of papaya slice was taken as 30 × 15 × 10 mm. The fruit slices were dipped in 0.25 per cent potassium metabisulphite solution for 15 minutes to prevent browning reaction. The pretreated fruit slices were taken in the fruit holding pan and placed inside the osmotic reactor. Forty litres of

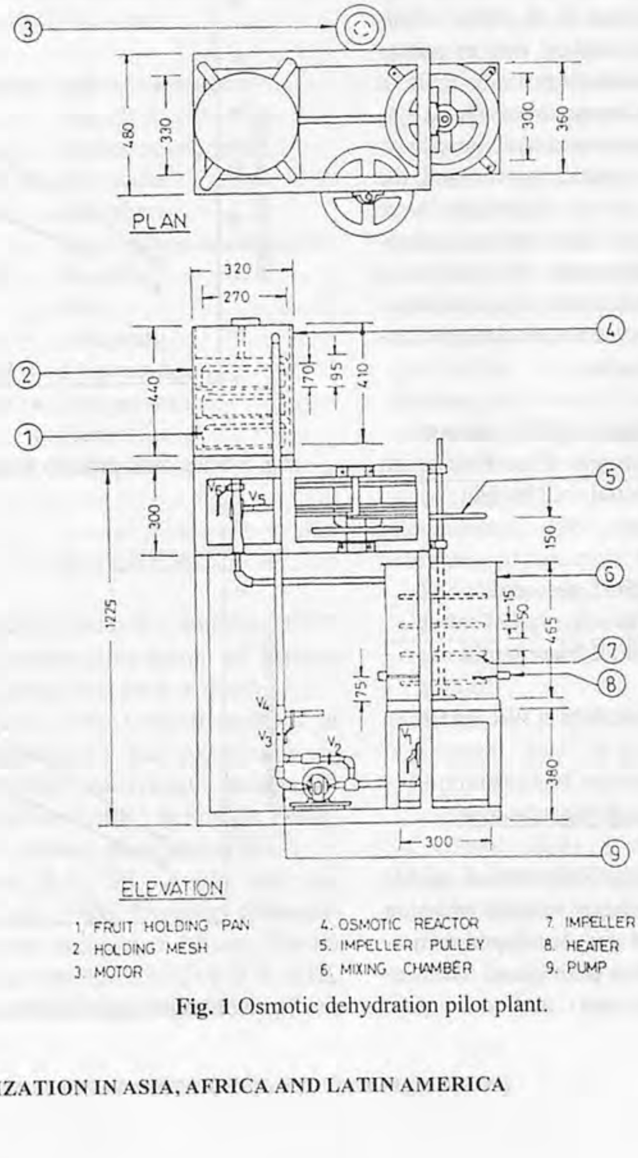

Fig. 1 Osmotic dehydration pilot plant.

60°B sugar syrup was prepared by mixing 31 kg of sugar and 20.5 kg of water. The ball valve No.1 was closed first and then 20.5 kg of water was measured and collected into the mixing chamber. The water in the mixing chamber was heated to 60°C and the impeller was rotated at 50 rpm. Sugar was added continuously and the impeller was rotated until clean sugar syrup is obtained. The temperature of osmotic syrup was maintained at 50°C using electronic thermostat control. The valve 3, 5 and 6 were closed and the sugar syrup was pumped to the osmotic reactor by the gear pump. The volumetric flow rate was maintained at 12 l min^{-1} by adjusting the bypass valve 2. After the syrup immersed the fruit holding pan by 50 mm, the valve No.5 was opened slightly and adjusted so that the outflow rate was maintained at 13 l min^{-1}. This continuous constant rate of pumping was maintained for 5 hours at 50°C syrup temperature. Sugar syrup, was maintained at constant level in the osmotic reactor and the inlet and outlet discharges were kept constant. The impeller was operated continuously. The water loss and solid gain during osmotic dehydration process were calculated using the formulae:

$$\text{Weight reduction (WR), percent} = \frac{\text{Initial fruit weight} - \text{Final fruit weigh}}{\text{Initial fruit weight}} \times 100$$

$$\text{Solid gain (SG), percent} = \frac{\text{Total solids} - \text{Initial solids}}{\text{Initial fruit weight}} \times 100$$

Water loss, percent = WR + SG

Results and Discussion

The osmotic dehydration of banana and papaya was tested using the designed and developed osmotic dehydration pilot plant. The water loss (percent) and solid gain (percent) during osmotic dehydration of banana and papaya is shown in **Fig. 2** and **3**. From the figure, it is observed that the water loss for banana was lower compared to papaya. This is due to the fact that the cell structure (plasmolemma) of papaya is weaker than that in the banana. The initial moisture contents of papaya and banana were 5.84 and 2.17 kg H_2Okg^{-1} DM, respectively. The moisture contents of the same fruits after osmotic dehydration were 2.088 and 0.9013 kg H_2Okg^{-1} DM. From the figure, it is observed that the solid intake in banana during osmosis was less than that of the papaya. This is due to the weak cell wall of papaya than banana. After osmotic dehydration the fruit slices were dried in hot air dried to safe moisture content for storage. During the initial period of air drying, there is a rapid increase in drying rate for two fruit slices. After this period of drying, the drying rate curves continue to decline, but more gradually and in a near linear fashion to equilibrium conditions.

Cost Analysis

The cost of the osmotic dehydration pilot plant, including hot air drier was Rs. 70,000 (US$ 1600). The energy required for operating this plant per day was approximately 6 kWH. Labour requirement was one women labour for cutting and one men labour for operating. The osmotic syrup, i.e., sugar solution was reused for 15 times. The cost of operation / h of this dehydration plant was Rs. 65 (US$ 1.5).

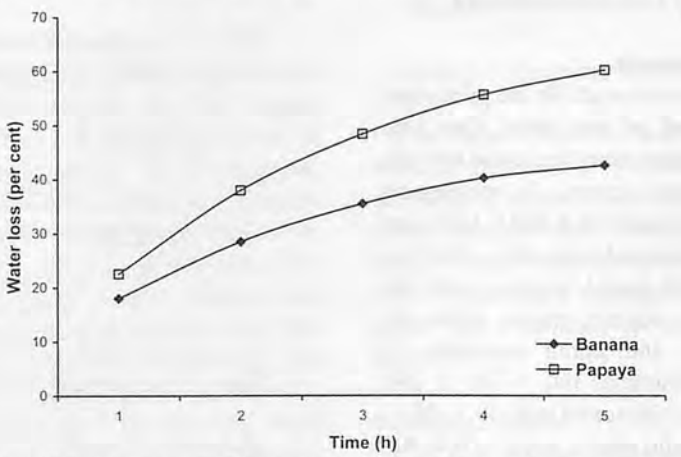

Fig. 2 Water loss (percent) during osmotic dehydration of banana and papaya.

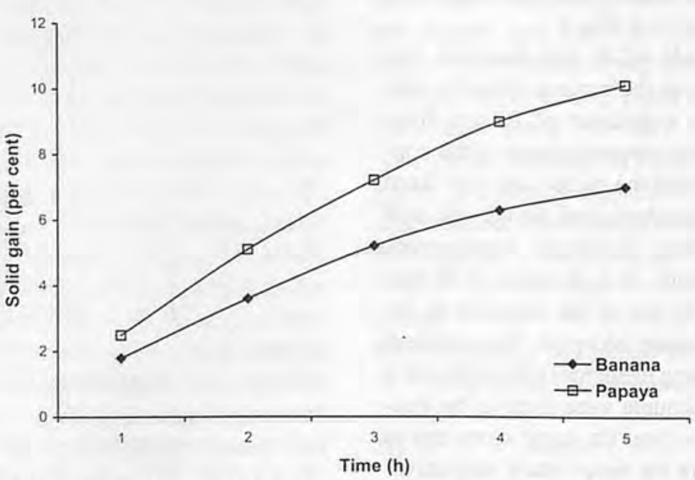

Fig. 3 Solid gain (percent) during osmotic dehydration of banana and papaya.

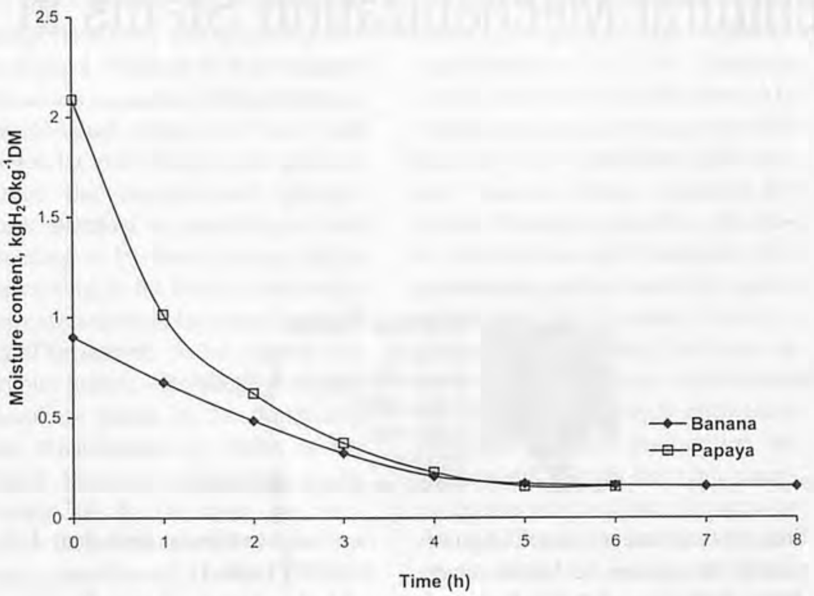

Fig. 4 Air drying characteristics of banana and papaya.

Table 1. Water Loss and Solid Gain during Osmotic Dehydration of Banana and Papaya (percent)

Time (h)	Water Loss		Solid Gain	
	Banana	Papaya	Banana	Papaya
1	18.03	22.55	1.80	2.5
2	28.50	38.02	3.60	5.1
3	35.50	48.40	5.20	7.2
4	40.20	55.62	6.30	9.3
5	42.50	60.08	7.00	10.1

Table 2. Any Drying Characteristics at Banana and Papaya

Time (h)	Banana	Papaya
0	0.9013	2.088
1	0.6750	1.014
2	0.4850	0.622
3	0.3240	0.375
4	0.2080	0.228
5	0.1710	0.158
6	0.1620	0.155
7	0.1580	-
8	0.1560	-

Conclusion

The designed and developed osmotic dehydration pilot plant was tested with two different fruits: banana and papaya. The sucrose syrup was circulated during osmotic dehydration at a flow rate of 12 $l\,min^{-1}$. The maximum water loss of 42.5 and 60.8 (percent) were observed for the banana and papaya, respectively, after 5h of osmotic dehydration after which the solid intake in banana and papaya were observed to be 7.0 and 10.1 percent, respectively. The cost of osmotic dehydration pilot plant for the dehydration of fruits was Rs. 70,000 (US$ 1600).

Symbols and Abbreviation

°B - Degree brix
°C - Degree centigrade
DM - Dry matter
et al - and others
g - Acceleration due to gravity
H_2O - Water
h - Hour
kg - Kilogram
kWH - Kilowatt hour
$l\,min^{-1}$ - litre per minute
Rs. - Rupees
US$ - US dollar

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A review of Agricultural Mechanization Status in Botswana

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Abstract

Agricultural mechanization in Botswana is predominantly animal draft-powered. The low yields which characterize the arable sector due to low and erratic rainfall causes continued reliance on government subsidies. Government assistance in the form of grants for machinery acquisition, draft power and cost of ploughing, constantly create possibilities for the use of tractor draft power, which become unsustainable once the subsidy is withdrawn. The period between 1980 and 1990 saw the greatest intervention by the government in the area of agricultural mechanization. Many schemes were formulated and tried. The Arable Lands Development Project (ALDEP), and drought relief schemes are the only ones still available to farmers. In the commercial farming areas, large-scale mechanization/tractorization has taken root during the same period.

Introduction

Botswana is mostly semi-arid; the greater part of the country receives between 300 and 400 mm of rainfall annually. Arable crop production is risky because chances of crop failure are high. Frequent droughts and uneven distribution of rainfall storms are to blame. Over 70% of the population of around 1.3 million (National Census, 1991) derive their livelihood from agriculture (livestock and crop production). The total land area is about 60 million hectares, with 3 - 5 million hectares used for arable farming. The average field size in the traditional sector is about 5 hectares. Commercial farms can be in excess of 1000 ha. Important crops grown are sorghum (Sorghum *Bicolor L. moench),* maize (*Zea mays*), millet (*Pennisisetum glaucum)* and cowpeas (*Vigna anguiculata)* in order of priority. Mixed farming is practiced by subsistence farmers. The national cattle herd, fluctuating at around 3 million head dominated the economy up until the mid-seventies, whereafter minerals (mainly diamonds) took over. Currently agriculture contributes less than 4 % of GDP (**Table 1**).

Mechanization of agriculture has, therefore, been dominated by the use of animal draft power. In excess of 200,000 head of cattle and 150,000 donkeys were available for draft power purposes during the late eighties (MoA, 1987), but the tractor numbers have also increased steadily from a mere 200 at independence in 1966 to more than 2,000 during 1985 and almost 6,000 in 1990 (MoA, 1990). This increase in tractor numbers is attributable to various government assistance schemes which were started in order to assist arable farming within this period. These schemes allowed tractor hire to be possible which, in turn, made tractor ownership viable.

The agricultural mechanization

Table 1. Agricultural Statistics for Botswana

1.	Total area × '000 ha	60,037
2.	Total land area × '000 ha	58,537
3.	Potential agricultural areas × '000 ha	5,330
4.	Cultivated area × '000 ha	1,330
5.	Forests, desert and others	53,207
6.	Cultivated land under	
	a) Large scale farms × '000 ha (% of cultivated area)	330 (25%)
	b) Small scale / peasant farms × '000 ha (% of cultivated area)	1,000 (75%)
7.	Irrigated land area × '000 ha	3
8.	Percent of total agricultural area cultivated	25%
9.	Percent of cultivated area irrigated	0%
10.	Methods of land preparation	
	b) Animal draft power % Number of households	56.4%
	c) Mechanical power (tractor) % Number of households	43.4%
11.	% Agriculture to GDP	3.4%
12.	% Agriculture to exports	2.7%

Adapted from Mrema G.C. and Patrick C, 1991.

set up is divided into two distinct categories. First and largest is the traditional. Farmers in this category broadcast a mixture of seed onto an un-ploughed piece of land and thereafter everything is ploughed in using the mould-board plough. Row planting is uncommon and weeding is by hand hoeing whilst harvesting is by hand. Land holdings are anything between 5 and 10 ha. The second is the commercial arable sector, comprising of the Barolong farms in the South and the Mpandamatenga farms in the North. Farmers in this category cultivate 500 ha or more and they grow crops predominantly for export (sunflower, cotton, winter wheat and maize). Sorghum is not preferred for the low returns it gives. The machinery compliement is dictated to by the large farm sizes and, therefore, comprises of large fleets of tractors per farm and may include some combines. The objective of this paper is to review the status of agricultural mechanization in Botswana and suggest ways of improving it.

Agricultural Policy Framework

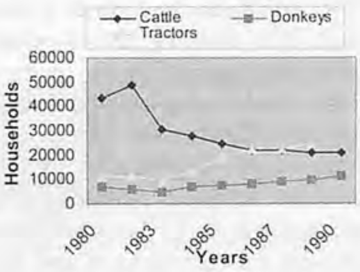
The agricultural policy acknowledges the importance of animal draft power in crop production. It states that animal draft power will continue to be a sustainable alternative for the majority of farmers. Timeliness of ploughing and condition of draft animals at the beginning of each season necessitates the use of alternative draft power sources. In this regard, investigations into the use of small tractors are to be continuously pursued (GoB, 1991). Overall, the policy promotes food security as opposed to food self-sufficiency. That is, the government is prepared to support only those food programs which are economically justifiable. All other food requirements should be imported.

As far as the importation of machinery is concerned, it is subject to the conditions of the Customs Union Agreement for Southern African countries, administered by the Ministry of Commerce, Industry and Tourism. These countries include; Botswana, Lesotho, Namibia, South Africa and Swaziland. The agreement requires that all the good, which enter the Customs Union region be levied a duty only once at the original entry point into the area. No individual country is allowed to negotiate separate importation arrangements. Goods from one country to the other within the area do not need import permits. Duty tariffs are reviewed periodically. Tractors attract the largest duty at about 40%, whilst most implements attract less depending on the amount of processing carried out on the said goods. Inside the country the 10% sales tax has been cushioned by manufacturing rebates on raw materials in an effort to allow local manufacturing companies to compete with those importing agricultural machinery.

Interventions of Assistance Programs

The financing of mechanization technologies in most developing countries tends to be difficult. These technologies unlike commodity research are costly, as farmers need to buy, hire or modify their machinery in order to adopt any new recommendations. Credit facilities are usually required, but whether these should be availed of through public institutions or commercial banking channels can be politically sensitive. This is because often farmers require only small amounts of credit, therefore, it is costly to administer and also they are isolated with little or no collateral (Gifford, 1990). The government, therefore, introduced several assistance programs during the 1980's, in order to assist farmers with the financing of mechanization technologies, particularly draft power.

Among the programs introduced were the Arable Lands Development Project (ALDEP) and the Accelerated Rain-fed Arable Program (ARAP). ALDEP was introduced in 1982 with financing through a loan from the African Development Bank and support from the International Fund for Agricultural Development (IFAD). The Food and Agricultural Organization (FAO) provided technical assistance. The program was targeted at those farmers with less than 10 ha of land and owning less than 40 head of cattle. The maximum assistance one could get was initially up to P2000.00 (US$2000.00) as a grant. This figure has, however, been progressively reviewed upwards in local currency terms, although in US$ terms it has remained the same (Mrema and Patrick, 1991). The package now includes agricultural implements, fencing materials, animal draft power (oxen or donkeys), water catchment tanks and donkey carts. For draft power a down payment of 45% of the grant is required, for fencing it is 25% whilst it is 15% for all other components of the program. ALDEP was meant to increase agricultural production by making available the necessary inputs (mostly hardware). ARAP on the other hand was started during the 1985/6 cropping season as a five-year project, with an estimated operational budget of P29 million (US$22 million). ARAP assisted all farmers with the following components: ploughing P70.00 (US$36.00) per hectare, up to a maximum of 10 ha, planting P20.00, free seeds to plant up to 10 ha, land clearing, fencing and water development up to a maximum of P20000.00 (US$10500.00). At the end of the project during the 1990-91 cropping season, more than US$30 million had been spent (Mrema and Patrick, 1991). Notable was the impact of the program on agricultural mechanization. Many farmers, merchants and civil servants acquired tractors through a variety of ways to service an increased demand for tractor hire (**Fig. 1**). Following the termination of ARAP,



Source: Agricultural Statistics reports (1980 - 90).

Fig. 1 Trend in draft power usage.

several drought relief measures (with grants to ploughing) were implemented, suggesting farmers ordinarily could not afford to pay for tractor hire services without government grants.

Draft power

Most of the farm operations in the traditional sector are carried out using human labour and or animal draft power. Both cattle and donkeys are used. Cattle were predominantly used before independence, but since about 1981, their use declined whilst donkey usage increased around 1983, when government schemes such as ALDEP which encouraged their use were introduced. Tractor draft power, on the other hand, despite the low returns to arable production is now the preferred source of draft power (**Fig.1**). ARAP and drought relief programs led to increased tractor usage which, in turn, led to an increase in their numbers. ARAP was terminated during the 1990/91 cropping season, but drought relief (given only if the government declares a drought year), and ALDEP are still available to farmers. The assistance for drought relief usually includes free seeds and a grant for ploughing on a hacterage basis.

Donkey draft power is preferred for planting compared to that of cattle. More than 95% of households who use cattle for draft power, broadcast their seeds and only 3% use them for row planting, whilst almost 12% of households who use donkey draft power row plant with them (**Table 2**). Good temperament of donkeys could explain why they are a preferred choice for planting.

Agricultural Implements

Crop Production Implements

Common farm implements are: single and double bottom mouldboard ploughs, single and double row planters/seed drills, cultivators, harrows, hand hoes and knives for the harvesting of cereals. Only a few farmers have access to fertilizer spreaders, sprayers and dusters. Efforts by the Ministry of Agriculture to keep some implements at the homes of local Agricultural Demonstrators (AD), for farmer use, have not bore fruit, since farmers are not willing to use implements which have been used by other farmers for fear of receiving 'undesirable spells' from those farmers. While the amount of use of some equipment such as single furrow ploughs, cultivators and harrows has remained the same, there are those whose usage has increased over time. These include the double furrow plough, the single and double row planters (**Table 3**). Though not conclusive, government schemes, which made acquisition of equipment possible, could have impacted on the numbers of equipment available in the regions and their usage. The modified IRRIC rice threshers are now available to farmers through the ALDEP program, for threshing of sorghum. The threshers are a welcome relief to farmers who have previously threshed with sticks. Production of both sorghum and maize meal is predominantly through the use of commercial hammer mills. These mills have increased in numbers because of financial packages farmers obtain through the Financial Assistance Policy (FAP). This is a welcome relief to many households,

Table 2. Distribution of Households and Draft Power Use for Planting (Unit: Number of households)

Type of draft power	Broadcast	Row plant	Broadcast (Row plant	Row plant (by hand)	Total
Cattle	20,250	600	100	200	21,150
Donkeys	9,550	1,300	100	50	11,000
Tractors	20,800	3,750	300	-	24,850
Others	4,100	850	450	900	6,300
Total	54,700	6,500	950	1,150	63,300

Source: Agricultural Statistics Report (1990).

Table 3. Distribution of Householdsand Usage of Common Agricultural Implements (Unit: Number of households)

Equipment type	1968/9	1977	1981	1983	1984	1985	1987	1990
Single furrow plough	65,647	60,550	55,600	35,880	48,750	54,650	53,550	70,400
Double furrow plough	6,007	9,337	11,800	9,260	12,600	8,650	25,750	29,800
Single row planter	2,515	4,977	1,250	1,260	3,350	3,100	5,050	8,500
Double row planter	2,167	3,815	1,200	1,880	2,350	1,700	6,150	7,700
Harrow	5,336	6,894	950	2,380	1,600	3,450	4,350	6,300
Cultivator	-	4,062	850	2,080	2,500	3,150	3,500	4,950
Tractor	4,519	6,147	12,950	11,850	17,350	5,100	3,150	5,900

Source: Agricultural Statistics Report (1990).

since traditionally the wooden mortar and pestle have been used to grind sorghum and other cereals to produce flour for their staple diet of (*bogobe)* porridge.

Water Pumping

Botswana is a borehole country with more than 15,000 registered by the department of water affairs. Borehole depths are varied, from as shallow as 5 m to anything in the region of 200 m. Wells in the Makgadikgadi area are shallow, usually less than 5 m depth. Pumping of water in this area is done by two stroke engines (2-5 Kilowatts) driving small impellers. Boreholes of the western Kgalagadi can be anything up to 200 m, and, therefore, are powered by 10-15 Kilowatts diesel engines.

Research and Development

Marginal rainfall compounded by inefficient cultivation methods are major causes of low yields for arable crop production in Botswana. Most research interventions, including mechanization have improvement in crop yield, as an objective. Agricultural mechanization, on the other hand, has as specific objectives: the improvement of operation efficiency and reduction of operation time. Several research efforts in the area of crop improvement were initiated in the early seventies, through donor projects. The British Dry-land Farming Research Scheme (DLFRS), targeting tillage and water conservation was one, and consisted of two phases 1971-1974 and 1975-1979. The second designed to develop implements for the implementation of DLFRS technologies, was the Evaluation of Farming Systems and Agricultural Implements Project (EFSAIP, 1976-1984). The other donor project was the Agricultural Technology Improvement Project (ATIP, 1982-1990). All these projects addressed tillage systems, machinery development and their combined effects on the yields of cereal crops. Aspects of machine efficiency and improvement of machine operation were secondary.

Research on implement design, testing and evaluation is currently carried out at the Farm Machinery Development Unit (FMDU) of the Department of Agricultural Research, the Rural Industries Innovation Centre (RIIC) and more recently, the Department of Agricultural Engineering and Land Planning of the Botswana College of Agriculture (BCA). FMDU successfully developed and released several animal powered implements, notably the Sebele range of planters consisting of the Sebele Planter, double and single furrow plough-planters. RIIC continues to adapt technologies from all over the world, examples of which are; sorghum dehulling and milling machines, water pumping equipment, various solar power and food processing technologies.

Institutional Support

The availability of agricultural machinery manufacture and repair facilities determines to a large extent, the success or failure of most mechanization programs. The RIIC has made good progress in this area, by coordinating the manufacture of most agricultural machinery developed in the country (specifically the Sebele range of equipment). Several artisan metal workshops have been sponsored, and are assisted to get quota for the fabrication of jigs for the manufacture of implements, such as Momoso (Kanye), Temo Engineering (Mochudi), etc. Black-smithing has also been revitalised, and several workshops built to back up the manufacturing base. Equipment from the Southern African region (South Africa and Zimbabwe) also find their way into the country at a cheaper cost. However, these cheaper implements often create problems of poor performance and lack of spare parts. The extension services of the Ministry of Agriculture provide the administrative support through the dissemination of information and financial appraisal for the utilization of government schemes, but lack mechanization supporting expertise.

Prospects

The intervention by the government through subsidies to agricultural mechanization technologies has not produced the expected increased crop production. In general, agricultural production does not benefit when farmers are given hand outs to pay for ploughing expenses. Assisting farmers to obtain hardware which they do not use is not beneficial either. Future subsidies should, therefore, be directed to only those farmers who are in a position to show that they will be able to use the equipment. Farmers should not be given money, but assisted to produce. A more realistic arrangement is to change the strategy from input subsidy to output subsidy, whereby farmers will be paid more for the produce and not before producing. The ALDEP scheme should assist farmers to buy equipment, which has been performance evaluated by the various research organs such as DAR, BCA and RIIC.

There is a lot of scope in the research of proper harnessing systems, acceptable methods of keeping well-trained teams of animals for timely cultivation at the beginning of each season. The farm mechanization unit of the Department of Crop Production and Forestry in the Ministry of Agriculture, if properly guided, should be in position to sensitize farmers on the advantages of good tillage techniques and proper use of agricultural equipment.

The repair and maintenance program for agricultural machinery will continue to be a difficult undertaking due to the vastness of the country and the distances between villages and farms. The provision of service centers at commercial farming areas such as Barolong and Mpandamatenga, could however be a possible option for the provision of repair and maintenance services. Artisan and blacksmith services, should also be included in assistance programs such as the Financial Assistance Policy (FAP), so that small workshops could be set up nearer to the farming communities.

The graduates of BCA Agricultural engineering diploma program (specializing in soil/water management) are expected to make impact, as they begin to find their way into the agriculture sector. Another diploma program specializing on agricultural mechanization would also go a long way in improving the effectiveness of extension and research services of the Ministry of Agriculture.

Conclusions

1. Agricultural mechanization is still dominated by animal draft power and will continue to be so for some time, due to the low returns to arable agriculture.
2. Repair and maintenance facilities are not readily available. The vastness of the country, and the high cost of setting them up by the private sector contribute to this state of affairs.
3. The research and development process of machinery, lead by DAR, BCA and RIIC is progressing quite well.
4. Machinery manufacture is still limited to the RIIC. Emerging companies find it difficult to compete with products from South Africa and Zimbabwe, because of low relative production costs in those countries.
5. Government assistance programs such as ALDEP have made impact by increasing machinery acquisition and donkey usage for draft power, even though crop output remained low.

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Appendix 1. Draft Power Usage by Households in Botswana

Year	Cattle	Donkeys	Tractors	Total
1980	43,300	6,700	11,350	61,350
1981	48,600	6,150	11,200	65,950
1983	30,700	4,650	9,400	44,750
1984	27,700	7,150	13,300	48,150
1985	24,800	7,700	19,000	51,500
1986	22,050	8,300	22,350	52,700
1987	21,800	9,300	22,600	53,700
1988	20,850	9,650	26,850	57,350
1990	21,150	11,000	24,850	57,000

Source: Agricultural Statistics reports (1980-90).

The Present State of Farm Machinery Industry

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Outlook of Agriculture

Trend of Agriculture

In 1998 agricultural total products was ¥6,306 billion, it occupied 1.2% of GNP. The imports agricultural products decreased $40.4 billion in 1996, $37 billion in 1997, $34 billion in 1998. But it increased $36.8 billion in 1999.

The exports agricultural products are $1.5-1.6 billion recently. But, in 1999 it increased $2.3 billion. In Japan, feed cereals, soybean, wheat and so on depend on the imports from foreign countries. Self-sufficiency ratio of agricultural products for food by calorie base in 1999 is 40%, cereals is 27%, it is same as preceding year average.

Population mainly engaged in farming has been decreasing yet, in 1999 it was 3 million persons. It was 4.6% of total working population. Farm house has decreased, in 1999 are 3,240,000 farm houses. And, commercial household was 76%. Arable land was 4,870,000 ha in 1999. Arable land per one farm family was about 1.5ha very small.

In Japan, food life has varied since 1970's. While, rice, oranges, milk, eggs and so on have been overproduced. In such surroundings, the GATT settlement require Japan to have more competitive power. In Japanese agriculture, it is requested to reduce production cost, increse people destined to bear agicultural production, produce various products satisfying consumers'need, and to realize agriculture keeping the earth favorable.

In July 1999, Japanese government enacted the New Agricultural Stable Law, which aims to assure constant food supply by raising domestic production, to encourage multi-functions of agriculture, to have sustainable development of agriculture and to promote the development of rural areas. The law makes it a target that 50% of national food consumption is covered by domestic production, at least to raise self-supply rate up to 45% by 2010. In 2000 Japanese government enacted guidelines for dietary patterns to imporve national dietary, the Food Recycle Law to decrese food waste, the revised Japanese Agricultural Standards(JAS) Law to improve food safety.

Trend of Farm Mechanization

Agricultural mechanization in Japan has remarkably progressed in the field of low land rice, chief crop, in a short period since 1955. At present rice production is almost mechanized from planting to harvesting. In 2000, working hours on 10a paddy field reduced to 34.2 hours from 117.8 hours in 1970.

In recent years farm machinery for rice crop is developed to be larger-sized, higher-efficiency and more commonly used. In addition, farm machinery for field crops and live stock farming is being developed and improved, which had been lagged behind so far.

From 1993 Japanese government started the program developing the new high-tech machine to make farm working efficient and to reduce farm burden. By 1998, 24 kinds of new type machines including big-size multipurpose combine and full automatic vegetable planter had been developed. Also to promote mechanization of vegetable cropping, standardization of vegetable cropping method was introduced for 11 kinds of vegetables. Moreover, in 1998 new program developing 28 types machine have started . Local governments have been developing the machine to vitalize special local products.

In 1995 Ministry of Agriculture, Forestry and Fisheries made a committee which studied method to reduce cost of farm product materials like farm machines. Those farm product materials are major parts of

Table 1. Major Farm Machinery on Farm — Unit: Thousand

Year	Walking type tractor	Riding type tractor	Rice trans-planter	Power sprayer		Power duster	Binder	Combine	Rice dryer
1990	2,185	2,142	1,983		1,871		1,298	1,215	1,282
1991	1,765	1,966	1,904	—		—	—	1,169	—
1992	1,786	2,003	1,881	—		—	—	1,158	—
1993	1,743	2,041	1,866	—		—	—	1,158	—
1994	1,669	2,060	1,835	—		—	—	1,149	—
1995	1,718	2,313	1,869		1,921		1,022	1,203	1,121

Source: "Statistical Yearbook of Ministry of Agriculture, Forestry & Fisheries" by the Ministry of Agriculture, Forestry & Fisheries and Other datas.

Table 2. Shipment Major Farm Machinery — Unit: Number

Year	Walking type tractor	Riding type tractor	Rice trans-planter	Power sprayer	Power duster	Binder	Combine	Rice dryer
1990	205,944	95,691	89,139	183,820	107,227	37,117	65,247	51,954
1992	199,141	88,754	80,105	184,016	105,028	20,888	60,941	52,275
1994	172,471	88,501	82,210	162,422	98,266	22,589	60,741	57,070
1995	163,323	90,623	81,729	162,352	96,499	23,293	64,572	60,564
1996	173,894	93,660	73,204	165,467	99,342	18,476	60,198	59,546
1997	174,004	87,416	64,859	177,064	90,133	16,770	53,095	52,389
1998	173,397	71,840	52,337	159,215	59,946	11,757	41,282	38,842
1999	180,511	72,533	59,529	166,380	54,717	12,010	40,822	39,416
2000	169,996	72,554	55,386	163,904	52,540	10,648	40.888	33,483

Source: "Survey of Shipment Agricultural Machinery" by the Ministry of Agr., Forestry & Fisheries.

farming cost. In 1996 concrete movement started in the field of production and distribution. Low cost machinery with limited functions has been increasing.

Following are the numbers of farm machines in possession of commercial farm household of Feb.1,2000: riding tractor reached 2,028,000 units; walking tractor 1,048,000; rice transplanter 1,433,000; head feed combine1,042,000 (**Table 1**).

Shipments of major farm machinery in the domestic market in 2000 are as follows: riding tractor reached 73,000 units (those under 20PS were 22,000; those 20-30PS 32,000; 30-50PS 13,000; over 50PS were 5,300); walking tractor 167,000; rice transplanter 55,000; combine 41,000(standard types were 1,263); grain dryer 33,000; huller 26,000. The shipment of safety cabins and safety frames attached to tractors rose sharply to 72,000 units (**Table 2**).

Recently more and more used farm machines are distributed. The rate used farm machinery in 1998 in the total sales amount is as follows: riding tractors 39%; rice transplanter 32%; combine 39%.

Movement of Farm Machinery Industry

Japan is a trade site. It is sure that Japan achieved economics power through trading various goods all over the world. Exporting sophisticated industrial goods, on the other hand, importing materials. Recently the import of agricultural goods increased. The import of agricultural goods oppressed domestic farmers. Government started safeguard on three products in order to protect Japanese farms.

There was a great changes in Japanese agriculture after World War Second. Especially, the number of farm households decreased sharply. It has influenced a lot of fields in Japanese agriculture. A production of domestic agricultural machines has fallen reflecting decreasing number of farm household.

And farm household has been dividing into two groups. One is small size farms, the other is large size. This situation has made machinery size into two groups. Almost agricultural machinery makers have began to dealt with this problem.

Without aged people and women, we can not talk about Japanese agriculture. These people support agricultural production in Japan. It is necessary for Japan to develop machinery for aged people and women. A lot of makers have developed these already. This demand will get stronger and stronger.

Scrapped agricultural machinery is large problem. Waste is the biggest problem in Japan. Many agricultural dealers are having difficulty handle with scrapped machinery. There is no place to dump.

We must build a recycle system in agricultural machines as soon as possible.

Trend of Farm Machinery Production

Farm machinery production in 2000 amounted to ¥548.5 billion (1.6% increase over the preceding year).

Production of the major farm machinery is as follows: Riding tractor 163,536 units increased by 4.5% over the preceding year. Seeing by h.p., those under 20PS amounted to 57,337 units, 20-30PS 47,793 units, over 30PS 58,406 units. Over 30PS class has been increasing the previous year.

The production of walking tractor amounted to 243,995 units, which showed a decrease of 3.9% under the preceding year. Under 5PS was 149,158 units, over 5PS was 94,837 units.

The production of combine, which is next to the riding tractor is 41,137 units (a decrease of 2.5% under the preceding year). The most popular type is with harvesting width of one meter head feed.

Following are the production of other types of farm machinery; rice transplanter amounted to 56,784 units (a decrease of 2.3% under the preceding year), binder (walking type harvesting machine for rice and wheat, barley etc.) 11,291 units (a decrease of 4.4%), thresher 5,586 units (an increase of 1.4%), grain dryer 38,476 units (an increase of 4.2%), huller 38,183 units (an increase of 1.6%), bush cleaner 1,011,889 units (a decrease of 6.7%), power pest-controller 251,359 units (an increase of 5.5%) so on (**Table 3**).

Trend of Farm Machinery Market

In Japan distribution systems for farm machinery is roughly divided into two major channels; the dealers concerned and Agricultural Cooperatives Association. As of June 1997, the retail shops were recorded to about 8,800, the employees amounted to 45,000 persons, and the annual sales amounted to ¥1,265.9 billion (**Table 4**).

Table 3. Yearly Production of Farm Machinery

Unit: Number, Million Yen

Year	Farm machinery total		Riding type tractor		Walking type tractor		Rice trans planter		Power sprayer		Power duster		Blower sprayer	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
1990	—	585,561	115,939	198,557	269,027	38,248	91,141	52,462	220,528	12,339	149,789	5,575	9,565	9,514
1991	—	615,131	148,437	203,260	270,714	40,102	87,019	54,265	198,887	10,607	163,306	6,155	9,318	12,766
1992	—	575,986	145,948	195,189	245,675	35,917	80,540	50,760	181,475	7,826	162,040	6,548	9,923	14,884
1993	—	588,627	146,115	186,983	225,564	33,738	84,980	58,344	165,909	6,899	134,901	5,985	8,559	12,155
1994	—	606,279	156,039	198,278	212,539	30,921	85,837	66,726	141,556	6,569	123,268	5,670	6,260	8,261
1995	—	649,874	153,890	205,489	205,758	28,271	86,713	69,218	161,360	7,370	129,995	6,293	7,018	11,622
1996	—	637,209	152,956	201,357	214,702	31,400	70,614	57,581	154,260	6,752	126,594	6,121	8,280	12,843
1997	—	615,974	160,518	219,446	225,229	31,803	63,367	53,236	172,034	7,776	110,736	5,278	7,799	10,223
1998	—	491,973	144,774	194,954	212,551	29,669	53,122	46,218	156,890	7,256	86,535	4,086	7,973	9,204
1999	—	539,960	156,452	220,047	253,817	36,365	58,137	43,146	153,118	7,416	77,693	3,567	7,194	9,282
2000	—	548,473	163,536	228,174	243,995	32,228	56,784	47,795	162,527	7,763	82,832	3,607	6,000	9,896
(2001)	—	252,817	70,212	99,688	111,398	14,536	31,819	28,176	81,527	3,569	43,830	1,637	3,723	5,432

Year	Grain reaper		Brush cutter		Power thresher		Grain combine		Rice husker		Dryer		Grain polisher	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
1990	42,502	11,110	1,601,652	25,798	22,634	9,118	68,993	138,396	60,006	18,332	59,269	39,990	58,500	4,871
1991	37,782	9,542	1,657,897	27,117	20,337	7,898	72,913	152,827	60,690	19,124	57,747	43,250	57,625	5,243
1992	30,511	7,753	1,890,427	28,994	12,656	4,838	65,673	143,335	50,208	15,292	51,821	38,236	45,182	4,274
1993	27,286	7,173	1,588,837	27,339	11,663	4,562	65,192	149,867	41,664	14,129	56,079	44,224	40,368	3,844
1994	21,033	5,379	1,554,478	28,726	11,422	4,439	61,242	148,537	42,115	14,680	62,044	49,846	53,514	5,493
1995	27,562	7,484	1,471,192	27,731	12,422	4,751	66,767	162,329	56,792	21,178	67,700	56,215	56,590	6,755
1996	21,541	6,364	1,220,005	24,291	11,593	4,568	63,371	168,391	60,021	22,639	64,969	53,483	44,451	6,096
1997	15,027	4,283	948,178	21,071	9,042	3,542	56,709	152,627	56,887	21,434	56,647	46,529	42,391	5,148
1998	8,631	2,336	1,012,372	22,236	5,102	1,988	40,196	103,435	28,113	10,705	32,968	26,543	39,729	3,588
1999	11,816	3,436	1,084,889	24,172	5,508	2,228	42,173	112,145	37,579	14,491	36,920	29,976	36,342	2,464
2000	11,291	3,207	1,011,889	23,132	5,586	2,154	41,137	109,469	38,183	14,589	38,476	32,413	33,741	2,175
(2001)	4,435	1,179	575,900	12,237	2,456	877	15,825	43,219	18,655	7,256	17,470	15,197	16,991	3,345

Source: "Survey of Status of Machinery, Production" by the Ministry of International Trade and Industry. Data by Japan Agr. Machinery Manufactures' Assn. and Land Internal Combustion Engine Manufacturer's Assn.

Note: Data for 2001 are forecast by Farm Machinery Industrial Research Corp.

Table 4. Farm Equipment Distributor and Sales Value

Unit:Million yen

Year	Number of retailers (1)	Employes	Annual sales value (2)	Inventory	Square meters of shop m^2	Annual sales value (2)/(1)
1979.6	9,257	48,548	1,007,298	159,772	898,854	108.8
1982.6	10,084	49,081	1,018,983	164,269	1,005,546	101.0
1985.6	9,142	43,921	946,507	144,837	985,453	103.5
1988.6	9,444	45,952	1,015,304	159,798	923,726	107.5
1991.6	9,480	45,705	1,158,924	170,104	984,700	122.2
1994.6	8,838	43,112	1,128,087	166,298	978,788	127.6
1997.6	8,820	45,090	1,265,902	170,350	901,851	143.5

Source: Ministry of International Trade and Industry.

Table 5. Handling of Farm Equipment by Agricultural Cooperative Association (1998 Business Year)

Unit: Million yen

Business year	Total number of coops. surveyed	Purchase in this term	Of which purchased through affiliated organs	Amount of supply and handling
1990	3,591	349,521	268,763	375,660
1992	3,204	354,728	268,393	388,031
1994	2,669	378,660	281,625	417,474
1995	2,457	374,952	283,193	413,664
1996	2,331	374,334	279,070	415,691
1997	2,112	310,008	229,205	342,423
1998	1,840	274,510	200,124	313,107

Source: "Statistics on Agricultural Cooperatives—1995 business.

According to the governmental survey by Ministry of Agriculture, Forestry, the total sales of farm machinery by Agricultural Cooperative Association reached ¥309.7 billion in 1999 (¥313.1 billion in 1998) (**Table 5**). In 1999 the number of Agricultural Cooperative was about 1,600. Amount of dealing machines per Cooperatives is about ¥190 million.

About half of dealers are small firms which employ less than 5. In a long time view, it is an important problem to improve management structure.

Export and Import of Farm Machinery

Export

In 2000 the export of farm machinery amounted to ¥139.0 billion, which showed a decrease of 6.7% under the preceding year. The ratio of exports to the total production amounts to ¥548.5 billion ended 25.3%.

Seeing by the destination, ¥79.7 billion for North America (an increase of 2.6%), ¥20.0 billion for Asia (a decrease of 14.9%), ¥29.8 billion for Europe (a decrease of 11.3%). For North America, ¥74.9 billion was for U.S.A., tractor 74,051 units, ¥64.3 billion, which was a major part (**Table 6**).

As for the types of farm machinery, tractor was chiefly exported; 119,420 units were exported in 1999 (the total production was 163,536 units), It amounted to ¥85.5 billion. Seeing by horse power, those under 30PS amounted to 78,765 units, those from 30 to 50PS 32,974 units, those over 50PS 7,681 units.

Major farm machinery, next to tractor, is bush cleaner. The total exports were 1,019,716 units, ¥22.3 billion. The exports of other farm machinery are as follows; walking tractor 69,127 units; power sprayer

Table 6. Export of Farm Equipment 1999

Unit: FOB million yen

Year	Unit	Value	Ratio	Major destinations
1990		132,757		
1991		129,943		
1992		143,891		
1993		124,505		
1994		120,079		
1995		104,597		
1996		113,586		
1997		130,351		
1998		143,843		
1999		149,066		
2000		139,049	100.0	U.S.A., France, Taiwan
Power tiller	69,127	3,893	2.8	France, Germany
Wheel tractor	119,420	85,547	61.5	U.S.A
Seeder, Planter	1,464	1,324	1.0	Taiwan
Power sprayer	42,808	1,345	1.0	Korea, U.S.A, Taiwan
Duster	12,194	326	0.2	Korea
Lawn mower	47,028	4,251	3.1	France, Germany, U.S.A,
Brush cutter	1,019,716	22,305	16.0	U.S.A., France, Italy
Mower	29,888	488	0.4	U.S.A., Malaysia, Korea
Combine	1,240	3,419	2.5	Taiwan, Korea China
Chain saw	174,390	3,492	2.5	France, U.S.A., Italy
Other	—	12,659	9.0	

Source: "Ministry of Finance. Totaled by Japan Farm Machinery Manufacturer's Assn.

Table 7. Import of Farm Equipment 1999

Unit: CIF million yen

Year	Unit	Value	Ratio	Exporters
1990		33,205		
1991		26,598		
1992		25,778		
1993		25,578		
1994		27,779		
1995		27,015		
1996		33,542		
1997		33,069		
1998		27,513		
1999		23,308		
2000		25,825	100.0	Germany, U.S.A., U.K.
Wheel tractor	2,537	8,931	34.6	U.K., France Germany,
Pest control machine	2,747,296	1,409	5.5	China, U.S.A., Taiwan
Lawn mower	41,178	1,651	6.4	U.S.A., Sweden, Germany
Mower	6,557	903	3.5	Italy, France, Netherlands
Hay making machine	1,130	740	2.9	France, Netherlands Germany
Bayler	560	888	3.4	France, U.S.A Germany
Combine	90	1,090	4.2	Belgium, Germany
Chain saw	46,524	977	3.8	Germany, Sweden, U.S.A.
Other	—	9,236	35.7	

Source: "Ministry of Finance. Totaled by Japan Farm Machinery Manufacturer's Assn.

42,808 units; lawn mower 47,028 units; grass mower 35,667 units; chain saw 174,390 unit, etc.

Import

In 2000 the imports of farm machinery amounted to ¥25.8 billion, which means an increase of 10.8% over the preceding year.

Followings are the major imported farm machinery: tractor 2,537 units (those more than 70PS were 2,024 units of all the tractor); chain saw 46,524 units, lawn mower 41,178 units, mower 11,416 units, fertilizer distributor 1,625 units. Tractors 960 units were imported from U.K. and about 400 units from each Italy, German and France (**Table** 7).

Trend of Research and Experiment

The surroundings of Japanese agriculture are very hard, because of claims for opening the market for agricultural products by U.R. Settlement, consumer's various favor, the decrease of the new farmers, being called for the contribution to solve the environmental problems. That's why the structural and technical reforms in Japanese agriculture are required urgently.

The research effort was chiefly made for high performance, automatic and popularized farm machinery in order to reduce burden of farm working. Electronics and mechatronics have been positively adopted for their technology. In 1993, the law to promote agricultural mechanization was revised. In 1993 "Urgent Development Program" started for the objective of developing machines critically needed by some farmers, but with low market demand. As a result, new machine like vegetables grafting machine came to market. And in 1998, new "Urgent Development Program" including 28 types study started.

In 2000, in the field of farm machinery of public research institutes, there were movement as follows;

In the field of tractor, auto-running systems have been developed. In the field of cultivating, high-speed puddling rotor has been developed, and using GPS system auto cultivating method has been developed.

In rice planting, planting a piece of rice weed by belt technology, which is sowing, raising and transplanting has been developing.

In the field of controlling plants, riding-type vehicle which weeds every direction in the paddy field has been developed and improved. And weeding machines, spot sprayer in orchards, multi-purpose vehicle in slope orchards, a multi-purpose monorail.

In the field of harvesting, very small size combine, harvesting machinery for cabbage, processing machinery for Welsh onion has been developing.

In the field of livestock, making stack-silo machinery and roll baler which cut long plants into small size machinery has developed.

In the field of human technology and safety, check list was made in order to assess comfortability by radar chart method, electronics information system which supplying death accidents and safety has developed. ■■

The Japanese Society of Agricultural Machinery

by
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Introduction

The Japanese Society of Agricultural Machinery (JSAM) was established in 1937 to promote and develop science related to agricultural machinery, agricultural structures and agricultural mechanization.

Agricultural machinery, such as tractors, rice transplanters, combines, and dryers have shortened the farmers' working hours, freed farmers from back-breaking labor, improved the yields and quality of crops, and enabled large-scale farm management. Today, agricultural machinery is not only a driving force but also an indispensable factor for agricultural production. The JSAM has a proud history of contributing to the development and diffusion of various kinds of agricultural machinery and to the progress of scientific studies on agricultural machinery.

The JSAM has five branches established in the Hokkaido, Tohoku, Kanto, Kansai and Kyushu regions.

Each branch, like at the head office, holds lecture meetings and symposia and publishes branch reports.

Prime Publications

A major activity of the JSAM is the publication of relevant reports such as the JSAM journal, manuals and research results as follows:

1) Journal of the Japanese Society of Agricultural Machinery bimonthly Vol. 63, No. 1-6 in 2001
2) Proceedings of Annual Meeting of JSAM 2001, ¥6,000
3) Examination method manual of Agricultural Machinery and Institutions I, pp.310, 1977, ¥4,500
4) Pictorial book of Agricultural Machinery and Instruments in Japan, pp.161, 1979, ¥3,500
5) Glossary of Agricultural Machinery Technical Terms — Japanese - English and English - Japanese, pp.200, 1981, ¥2,000
6) 50-year History of the Japanese Society of Agricultural Machinery, pp.238, 1988, ¥4,500
7) Bioproduction Machinery Handbook, pp.1182, 1996, ¥25,750
8) Cost engineering of agricultural productive institutions, (JSAM Selected Book No. 4), pp.169, 1992, ¥2,300
9) Description of physical properties value of grain, (JSAM Selected Book No. 5), pp.149, 1992, ¥2,300
10) Automation and new technology of the agricultural productive institutions (JSAM Selected Book No. 6), pp.152, 1993, ¥2,300
11) Drying agricultural products using solar heat, (JSAM Selected Book No. 7), pp.160, 1994, ¥2,300
12) Developing and designing a spectro-separator for rice application, (JSAM Selected Book No. 8-9), pp.169, 2001, \2,300
13) THE XIV MEMORIAL CIGR WORLD CONGRESS, pp.385, 2001, ¥3,000
14) THE 5th TECHNO FESTIVAL — agricultural machinery development and the challenges of the new century. pp.198, 2001, ¥2,000
15) An investigation research report on technical support of small and medium-sized companies in fiscal year 2000, pp.455, 2001, ¥4,000

JSAM Presidents

Name	Period in office (Fiscal Year)
Tatsuzo Hirobe	1937-1946
Teiichi Nihei	1947-1962
Fusanobu Shoji	1963-1967
Hideo Kaburagi	1968-1970
Yoshichiro Yasuda	1971-1973
Ryoichi Matsuda	1974-1979
Akira Hosokawa	1980-1982
Noboru Kawamura	1983-1985
Ritsuya Yamashita	1986-1991
Osamu Kitani	1992-1994
Minoru Yamasaki	1995-1997
Yasuhisa Seo	1998-2000
Tomohiko Ichikawa	2001-

Members of the Board, 2001-2003

President
Tomohiko Ichikawa

Vice-Presidents
Tsuguo Okamoto
Tetsuiti Odawara

Directors
Akihiko Onoda (Chairperson, General Affairs Committee)
Yasuhiro Sasaki (Chairperson, Financial Committee)
Akira Oida (Chairperson, Editorial Committee)
Takeshi Kita (Chairperson, Planning Committee)
Hisashi Horio (Chairperson, Information Committee)
Haruhiko Murase (Chairperson, International Exchange Committee)
Noriaki Ishitsuka (Chairperson, Future Planning Committee)

Akira Akase (Responsible for Annual Meeting)
Masateru Nagata (Responsible for Annual Meeting)
Kengo Watanabe (Responsible for Award Activities)
Hironoshin Takao
Kazuhiko Ito (Director, Hokkaido region)
Yoshio Nishiyama (Director, Tohoku region)
Masayuki Koike (Director, Kanto region)
Mikio Umeda (Director, Kansai region)
Koichi Hashiguchi (Director, Kyushu region)

Auditors
Fumitake Ishikawa
Tsukasa Nagaki

Councilors (100 persons)

Number of members and annual membership fees

Honorary members	12	None
Regular members		
(Domestic)	1056	¥9,000
(Overseas)	53	¥9,000
Student members	154	¥4,000
Subscribing members	110	¥12,000
Special members	50	¥50,000*
Total	1435	¥84,000

Note: * minimum unit fee

Other Activities

Other activities of he JSAM are annual meetings and awards (academic, Mori Technical, and research encouraging as follows:

Annual Meetings
2001 April 1-4 at Tottori University
2000 Niigata University
1999 Saga University
1998 Yamagata University
1997 Mie University
1996 Hokkaido College, Senshu University
1995 The University of Tokyo
1994 Kyushu University
1993 Hirosaki University
1992 Tokyo University of Agriculture & Technology
1991 Kyoto University

Awards
1) Academic Award
2001 Kenji Sakai [Theoretical Analysis of Nonlinear Dynamics and Chaos in Bouncing Tractor]
2000-1991 S. Kondo; M. Kadota, S. Tanaka, N. Noguchi, K. Araya, E. Inoue, M. Umeda, T. Okamoto, K. Fujiura, M. Ura
1990-1981 K. Hashiguchi, Y. Sasaki, F. Ishikawa, K. Miura, A. Oida, K. Kato, T. Iwao, Kawana, N. Ito
1980-1971 T. Abe, K. Namikawa, S. Naka, O. Kitani, T. Ban, F. Ai, M. Tojo, K. Mori, T. Konaka, T. Okamura
1970-1961 S. Murata, H. Tanabe, K. Nakagawa, T. Takenaga, T. Yoshida, T. Aramaki, S. Yamazawa, K. Miyakita, S. Endo, J. Sakai, C. Nakamura, M. Wakui, A. Ishihara, S. Ishibashi, M. Matsuo, T. Tanaka, S. Umeda, R. Takeuchi
1960-1954 H. Kano, M. Tsuchiya, H. Shimizu, M. Imai, Y. Chuma, T. Tahara, M. Sonomura, S. Niizeki, J. Nagahiro, Y. Tamura, S. Masuda, H. Shoji, S. Morishima, S. Tsunematsu, R. Matsuda, H. Esaki, T. Sato, Y. Miyoshi, T. Watanabe, T. Nihei, N. Kawamura, H. Kaburagi, U. Tezuka, S. Mori, S. Tabuse

2) Mori Technical Award
2000-1991 O. Yukumoto, Y. Matsuo, N. Noguchi, K. Tosaki, S. Miyahara, Y. Mizukura, K. Tasaka, A. Ogura, M. Namoto, K. Kobayashi, M. Suzuki, A. Onoda, H. Otsuki, K. Inooku, N. Yamana, A. Hirata, T. Takigawa, T. Nanbu, K. Nishizaki, J. Sato, T. Yamada, S. Goto, T. Yamamoto, N, Ishitsuka
1990-1981 Y. Yamakage, T. Konishi, M. Horio, S. Yoshida, T. Akinaga, M. Karahashi, T. Ichikawa, T. Sugiyama, M. Manaka, Y. Nakamura, T. Murata, S. Morita, T. Takenaga, K. Tsuga, M. Kajiyama, N. Murai, M. Nagata, M. Suzuki, H. Esaki, S. Imazono, T. Sugiyama, M. Manaka
1980-1971 K. Kojima, N. Takamoto, S. Hayakawa, T. Kokusho, T. Kimura, S. Kinoshita, H. Yoshino, Y. Shimizu, S. Taharazako
1970-1963 R. Shimamoto, S. Hiyamuta, S. Takeda, T. Furuchi, R. Yamashita, S. Ueda

3) Research Encouraging Award
2001 N. Murakami [Development of Robotic Cabbage Harvester]
2000-1994 K. Ishii, M. Iida, S. Kondo, N. Noguchi
2000-1994 K. Ishii, M. Iida, S. Kondo, N. Noguchi

4)Technical Encouragement Award
2000-1994 R. Otani, Y. Yokochi, Y. Kawano, K. Kobayashi

Seminars or Symposia Held
1) 2001 December 11-12, International Workshop 2001 Agricultural Mechanization - Issues of Priorities in The New Century
2) 2001 November 30, THE 6th TECHNOFESTIVAL — The challenge to Eco-friendly technology, from farm to table —
3) 2000 December 8, THE 5th TECHNO FESTIVAL — agricultural machinery development and

the challenge to a new century —

4) 2000 December 20, The 2nd International Symposium in Sapporo 2000 — Electrical communications of the agricultural machinery using the LBS for agricultural bus system

International Exchange Activities

1) JSAM has published the Journal of the Japanese Society of Agricultural Machinery for over 60 years and is now publishing it every two months. Although English papers have also increased in number recently, many papers are written in Japanese.

However, since the English summary is attached to the Japanese paper, it is thought that our journal is also useful for overseas agricultural engineers.

2) The Societies of Agricultural Machinery of Japan, South Korea and Taiwan will form an international society under joint sponsorship, with the first society meeting to be held in Taiwan in November, 2002.

This international society meeting venue is to circulate among these three countries every two years; the meeting will be held, in Japan in 2004.

JSAM Head Office and Branch Offices

Head Office

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Branch Offices

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Applying for JSAM membership

Persons desiring to join the Japanese Society of Agricultural Machinery should fill in the necessary items in the "JSAM admission application form" then send the form to the Head Office by mail, facsimile or E-mail. Application can also be made from the JSAM home page. ■■

JSAM membership application form						
Classification		Regular Member	Student Member	Subscribing Member	Special Member	(Circle the classification desired)
Name						
Mailing Address		TEL				
Office	Name					
	Address	TEL E-mail:				
Birth Date						
Note						

The National Agricultural Research Organization and Prospective Farm Mechanization Research

by
Yasuhiro Sasaki
Director
Department of Farm Mechanization and Engineering
National Agricultural Research Center (NARC)
National Agricultural Research Organization (NARO)

Introduction

A central government office reorganization in Japan was conducted as part of an administrative reformation in January, 2001. Most of the national research organizations were switched over to an independent administrative institution in April of that year. The reorganization aimed to achieve a reduction in bureaucratic channels, hence increase the efficiency of administrative function. An efficient organization management should increase its achievement. Evaluation of the achievement is expected to be done by an outside neutral body.

Agricultural research organizations that hitherto belong to the Ministry Agriculture, Forestry and Fisheries (MAFF) for some 100 years are hencefourth operating now under the new system.

The organizations are the: National Agricultural Research Organization (NARO), National Institute of Agrobiological Sciences (NIAS), National Institute for Agro-environmental Sciences (NIAeS), National Institute for Rural Engineering (NIRE), National Institute for Food Sciences (NIFS) and the Japan International Research Center for Agricultural Sciences (JIRCAS). The main focus of the research activities of these organizations are briefly presented below.

The National Agricultural Research Organization (NARO)

NARO is entrusted with the development of technologies required to solve various agricultural problems not only by conducting specialized studies, but also by integrating and coordinating various studies resulting from the results of many researchers. Its main concern in the conduct and management of agricultural research is guided by five basic ideas; namely, the five Cs: Creativity, Competitiveness, Concentration, Cooperation and Clarity.

The NARO consists of its headquarters in Tsukuba while its 11 research institutes are located in different regions of Japan (**Figure 1**).

The total number of staff and personnel is 2,823 of which 1,473 are researchers.

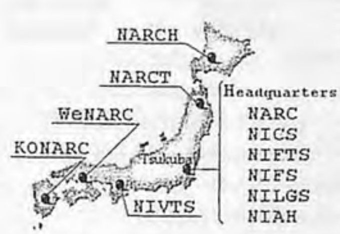
The respective missions of these research institutes are as follows:

The National Agricultural Research Center : (NARC)

The NARC carries out research to innovate crops production in Japan and leads investigations for the development of agricultural technologies suited to Kanto, Tokai and Hokuriku regions (central region in the country).

National Institute of Crop Science : (NICS)

The NICS undertakes basic research on the improvement of domestic crops production through the development of new varieties and physiological technologies to stabilize productivity and product quality. The NICS is the core of crop science in Japan.



Headquarters
NARC : National Agricultural Research Center
NICS : National Institute of Crop Science
NIFTS : National Institute of Fruit Tree Science
NIFS : National Institute of Floricultural Science
NIVTS : National Institute of Vegetable and Tea Science
NILGS : National Institute of Livestock and Grassland Science
NIAH : National Institute of Animal Health
NARCH : National Agricultural Research Center for Hokkaido Region
NARCT : National Agricultural Research Center for Tohoku Region
WeNARC : National Agricultural Research Center for Western Region
KONARC: National Agricultural Research Center for Kyushu Okinawa Region

Fig. 1 Location of the national agricultural research organization (NARO).

National Institute of Fruit Tree Science : (NIFTS)

The NIFTS carried out the basic research on the whole field of fruit industry, and is Japans' core institute of fruit tree science.

National Institute of Floricultural Science : (NIFS)

The NIFS is responsible for doing basic research in floriculture and is the country's core of floricultural science.

National Institute of Vegetable Tea Science : (NIVTS)

The NIVTS carries out basic research on vegetable and tea production to establish low cost but high quality production systems being the core institute of vegetable and science in Japan.

National Institute of Livestock and Grassland Science : (NILGS)

The NILGS performs research work on livestock industry, including forage crop production and waste management. It is the core institute of livestock and grassland science in Japan.

National Institute of Animal Health : (NIAH)

The NIAH does research activities to contribute to the sound development of the livestock industry. The NIAH is the core institute of veterinary science in Japan, and cooperates with the Animal Quarantine Service (AQS), National Veterinary Assay Laboratory (NVAL) and prefectural livestock hygiene service centers in the country as well as with many foreign veterinary institutions.

National Agricultural Research Center for Hokkaido Region : (NARCH)

The NARCH leads in investigations on the development of agricultural technologies primarily suited for the requirements in the Hokkaido region.

National Agricultural Research Center for Tohoku Region : (NARCT)

The NARCT leads research work on the development of agricultural technologies primarily suited for the peculiarities of the Tohoku region.

National Agricultural Research Center for Western Region : (WeNARC)

The WeNARC undertakes basic and applied research on the development of agricultural technologies suited for the Western region of the country.

National Agricultural Research Center for Kyushu Okinawa Region : (KONARC)

The KONARC carries out leading investigations for the development of agricultural technologies suited to the Kyushu Okinawa region.

*Website : http://www.naro.affrc.go.jp/index en.html, E-mail : www@naro.affrc.go.jp

Farm Mechanization Research in NARO

Research departments and laboratories concerning agricultural mechanization and/or improvement of farm work are shown in **Figure 2**. Investigations in agricultural mechanization and farm work are conducted in 5 research centers (NARC, NARCH, NARCT, WeNARC and KONARC) and 2 research institutes (NIVTS and NILGS). The specialty department on farm mechanization and engineering is arranged in NARC. In the department comprised of 5 laboratories, basic researches for farm mechanization and leading investigations in techniques suited to the central region in Japan are performed. In other laboratories of research centers and research institutes, various kinds of studies on farm mechanization are done by each organization.

Prospective of Farm Mechanization Research

Today, Japanese agriculture is confronted with various kinds of problems such as: decrease of self-sufficiency ratio in agricultural products for food; overproduction of rice; low productivity of wheat, soybeans, feed-crops and vegetables; environmental pollution in agriculture; and aging of farmers. To overcome these difficulties and to improve Japanese agriculture, it is essential to increase the overall productivity of lowland crops, to reduce production cost through intensive land utilization and expansion of farm scale. At the same time, the program seeks to improve safety and quality of agricultural products. Moreover, the NARO program proposes new agricultural technologies for environmental conservation and to increase the interest in the younger generation in agriculture as a career.

The research targets in farm mechanization are as follows.

1. Development of technologies for labor-saving, labor-lightening and low-cost:

a. Farm mechanization system rotating rice, wheat and soybeans in large-scale lowland areas;

b. Reduction technology in farm labor in hilly and mountainous areas; and

c. Automation technology in farm work, particularly in simultaneous travel system which can operate several middle and/or small size vehicles by one operator alone;

d. Systematization of mechanization on vegetable farms, particularly in the cultivation of cabbage, lettuce and others;

e. Labor saving technology in tea plantation and fruit orchards and;

f. Use of robots in most farm work

in agricultural facilities

2. Development of technologies in rendering farm work more safety based on ergonomic engineering:
   a. Analysis of the characteristics on farm work affecting the human factor; and
   b. Improvement of farm work and working environment in agricultural facilities.
3. Development of farm mechanization technology in the construction of agro-environmental conservation and practical use of resources:
   a. Resionable Precision farming in harmony with the environment;
   b. Protection of nitrate leaching in upland and tea farms;
   c. Recycling of domestic animal feces and urine;
   d. Individual precision feeding and management of domesticated animals;
   e. Use of liquid fertilizer in hydroponics; and
   f. Effective use of agriculture byproducts in biomass energy.
4. Development of technologies for improvement of machinery and facilities by sensing bio-information and its surrounding environmental information
   a. Real time measurement of crop growth;
   b. Analysis of optimum control system for crop growth and animal health; and
   c. Measurement of bio-material properties for bio micro-machines and mini-machines.
5. Development of pre-post harvest technology to improve high quality and added value of agricultural products

Organization — Department of Research — Lanoratory

- President
  - Senior vice president
  - Vice presidents
- Headquarters of NARO
- National Agricultural Research Center (NARC)
  - Dept.of Farm Mechanization and Engineering
    - Crop Production Mechanization Lab.
    - Instrumentation and Automation Lab.
    - Facilities Utilization Lab.
    - Agro-Energy Lab.
    - Farm Work System and Ergonomics Lab.
  - Dept.of Lowland Farming — Farm Mechanization Lab.
- National Institute of Crop Science (NICS)
- National Institute of Fruit Tree Science (NIFTS)
- National Institute of Floricultural Science (NIFS)
- National Institute of Vegetable and Tea Science (NIVTS)
  - Dept. of Fruit Vegetables — Farm Mechanization Lab.
  - Dept. of Tea
    - Cultivation Technique Lab.
    - Processing System Lab.
- National Institute of Livestock and Grassland and Science (NILGS)
  - Dept. of AnimalFeeding and Management
    - Forage Processing Engineering Lab.
    - Animal Husbandry Engineering Lab.
  - Dept. of Livestock Industry Environment — Waste Management Engineering Lab.
  - Dep. of Forage Production — Forage Production Engineering Lab.
- National Institute of Animal Health (NIAH)
- National Agricultural Research Center for Hokkaido Region (NARCH)
  - Depr. of Integrated Research for Agriculture — Agricultural Machinery Lab.
  - Dept. of Upland Agriculture — Crop Production Research Team
- National Agricultural Research Center for Tohoku Region (NARCT)
  - Dept. of Integrated Research for Agriculture — Agricultural Machinery Lab.
  - Dept. of Vegetable and Floricultural Sciences — Horticultural Machinery Lab.
- National Agricultural Research Center for Western Region (WeNARC)
  - Dept. of Hilly Land Agriculture — Hilly Land Farm Mechnization
  - Dept. of Crop Breeding — Lab.Mechanized Farm Work Lab.
- National Agricultural Research Center for Kyushu Okinawa Region (KONARCK)
  - Dept. of Lowland Farming Research — Agricultural Machinery Lab.
  - Dept. of Upland Farming Research — Farm Operation Mechanization Systems Lab.

Fig. 2 Research departments and laboratories on farm mechanization in national agricultural research organization (NARO).

a. Grain harvesting, processing and storage to keep high quality and low cost;
b. Technology that can offer clear agricultural products with cultivation history;
c. Drying and storage to keep high quality for high-moisture content grains
d. Effective conveying from field after harvest for leaf-and root-vegetables;
e. Intelligent mechanization of tea cultivation based on skills of exemplary good farmers; and
f. Restructuring transporting technology for high quality animal feed.

6. Establishment of farm operation system based on leading key techniques
a. Comprehensive field examination using new mechanization techniques;
b. Compound evaluation of farm work system by means of cost analysis and ergonomic method; and
c. Presentation of future farm work system through computer simulation technique.

7. Study of farming mechanization corresponding to international practices.
a. Reinforcement of close collaboration with advanced countries on basic technology;
b Promotion of technology transfer to developing countries; and
c. Reinforcement of technical study fitted ISO.

Integrated Studies on Development of Basic Techniques for Future Agricultural Mechanization

Background and Objectives

It has become increasingly important to give attention to the environment though crop production process as well as to reduce labor requirement and improve comfort in farm works. The conventional agricultural technologies may not be all compatible with letting environmental problems off and high productivity of crop production. In or to crop with this situation, new mechanized crop production system that realizes high productivity coupled with environmental harmony is required. Basic sensing techniques in crop growth and field conditions and automatic machine control technologies have been developed in phases one and two of this research project. In the third phase, mapping technologies in crop growth and soil condition in field and crop diagnosis techniques will be conducted in order to develop basic technologies for precision farming system covering all types of agricultural production in Japan.

Overview of Research

(1)Development of common principal technologies in precision farming such as soil nutrient and crop growth sensing, visualized database of crop and field information and automatic vehicle and implement control will be developed.

(2)Development of principal technologies for precision farming in paddy fields.
Growth diagnosis and control techniques in rice, wheat and soybean will be developed.
Prototypes of mechanized farm work system compatible with environmental issues and productivity will also be developed.

(3)Development of principal technologies for precision farming in upland field and pasture.
Growth diagnosis and control techniques in vegetable, pasture and forage crop will be developed.
Prototypes of mechanized farm work system compatible with environmental issues and productivity for vegetables, pasture and forage crop, will also be developed.

The Institutes in charge of these integrated studies are the: NARC, NGRI, NIRVOT, Hokkaido NAES, Tohoku NAES, Hokuriku NAES, Chugoku NAES and Kyusyu NAES for completion in the research period of 1994-2002. ■■

Education and Research Activities of Hokkaido University

by

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General Information

Hokkaido University (HU) is one of the largest national universities under the jurisdiction of the Ministry of Education, Culture, Sports, Science and Technology (MECSST) in Japan. It consists of 12 faculties, 14 graduate schools and many institutions, in which almost 4,100 staff members conduct advanced researches in various disciplines of science and humanities. There are some 17,433 undergraduate and graduate students annually in the University. On September 28, 2001, the HU celebrated its 125th year anniversary.

The origin of the faculty of agriculture can be traced back to the Sapporo Agricultural College founded in 1876 to promote colonization. This faculty has since been contributing to the development, research and extension activities in cold regional agricultural techniques such as the natural condition in the Hokkaido area.

The Hokkaido University is situated in Sapporo city where the 1972 Olympic Winter Games where held. It is between 41° 21' and 45° 33'N latitude, the northernmost islands in Japan. It is recognized as the biggest farm land in the country with paddy fields of 236,000 ha, upland fields of 413,800 ha and grasslands 533,500 ha cultivated by 70,000 farmers with a highly mechanized system representing 25% of the Japanese farmlands and 10% of the total national crop production.

Faculties and the Graduate School

Faculty of Agriculture

Students enrolled in the Faculty of Agriculture are expected to earn 50 credit units from one of three primary courses in general education, i.e., biological sciences, chemical sciences and general agricultural sciences. The Faculty offers studies in agricultural sciences in seven programs provided by the following seven departments: agrobiology and bioresources, applied bio-sciences, forest science, animal science, agricultural engineering and agricultural economics.

The Bioproduction Engineering Groups belong to the Department of Agricultural Engineering. The department works on two disciplines, namely; Land Improvement and Agricultural Machinery. The former consists of three research sections: Land Improvement and Management, Agricultural Physics, and Soil Amelioration. The latter consists also of three sections: Agricultural Vehicle Systems Engineering, Agricultural Process Engineering and Crop Production Engineering.

Environmental Information on Land and Agricultural Systems Engineering in the Graduate School of Agriculture also supports education in the Department.

Graduate School of Agriculture

The Graduate School of Agriculture consists of the following three divisions: Bioresources and Product Science, Environmental Resources, and Applied Bioscience.

The Graduate School of Agriculture offers a variety of programs leading to two graduate degrees: masteral and doctoral degrees in Agriculture. The students are supervised by individual graduate student committees of professors and stuff members.

The graduate curriculum consists of 6 research groups and one cooperative research: Botany and Agronomy, Horticultural Science and Landscape Architecture, Animal Production, Animal Product Science, Bioproduction Engineering, Agricultural Economics, and Northern Bioresouces.

Students are required to take at least 30 credit units for the masteral degree and 10 more credit units for the doctoral degree.

The Research Group of Bioproduction Engineering

This group consists of 4 laboratories: Agricultural Vehicle Systems Engineering, Agricultural Process Engineering, Crop Production Engineering, and Agricultural Systems Engineering. Their current research activities and staff are as follows:

Laboratory for Agricultural Vehicle Systems Engineering

Decision support system for tractor operation, co-generation system for anaerobic fermentation, development of agricultural mobile robots, vision sensors for field condition and artificial intelligence for agriculture.

Professor: Hideo Terao, Dr. Agr.

Associate Professor: Noboru Noguchi, Dr. Agr.

Assistant Professor: Kazunobu Ishii, Dr. Agr.

Laboratory for Agricultural Process Engineering

Post-harvest handling optimization techniques in rice and wheat grains, super low temperature storage for preserving rice quality, near infrared spectroscopy for quality evaluation of agricultural products, low temperature and high humidity condition for preserving quality of fruit and vegetables, electrolyzed water for disinfecting fresh market vegetables.

Professor: Kazuhiko Itoh, Dr. Agr.

Associate Professor: Shuso Kawamura, Dr. Agr.

Assistant Professor: Jun-ichi Himoto, Ms. Agr.

Laboratory for Crop Production Engineering

Farm mechanization, safety engineering in farm work, crop-row following control, crop recognition by image analysis, soil dynamics in tillage, site specific crop management, and agricultural robotics.

Professor: Shun-ichi Hata, Dr. Agr.

Associate Professor: Takashi Kataoka, Dr. Agr.

Assistant Professor: Hiroshi Okamoto, Dr. Agr.

Laboratory for Agricultural Systems Engineering

Aerobic and anaerobic treatments, utilization of agricultural and food wastes, utilization of natural coldness for purifying, waste and ice making, evaluation of soil compaction and farm mechanization for developing countries.

Professor: Juzo Matsuda, Dr. Agr.,

Associate Professor: Kazuhiko Ohmiya, Dr. Agr.

International Cooperation

International Academic Exchange

The Hokkaido University has a sister relationship exchange program with 16 universities in 5 countries for exchange research fellows, students and general information, and cooperation in joint research projects as follows:

University San Paulo, *Brazil*

Luiz Queiroz College of Agriculture, *Brazil*

Northeast Agricultural College, *China*

Shenyang Agricultural University, *China*

Northeast Forestry University, *China*

College of Agriculture, Chungbuk National University, *Korea*

College of Agriculture, Chungnam National University, Korea

College of Agriculture and Life Sciences, Kangwon National University, *Korea*

College of Forest Sciences, Kangwon National University, *Korea*

College of Animal Agriculture, Kangwon National University, *Korea*

College of Natural Resources, Youngnam University, *Korea*

Faculty of Agriculture, Kasetsart University, *Thailand*

Faculty of Forestry, Kasetsart University, *Thailand*

Faculty of Science, Mahiol University, *Thailand*

Bogor Agricultural University, *Indonesia*

Faculty of Agriculture, University of Plalaka Raya, *Indonesia*

Foreign Student Enrollment

Foreign students accepted in HU are divided into two categories, i.e., Japanese Government Scholarship Student and Non-Japanese Government Scholarship Student. The latter category includes not only students on their own funds, but also those who receive financial aid from their governments or organizations connected with their governments. Beside those on the Japanese Government scholarship, students of foreign nationalities may be allowed in academic programs through special admission procedures different from those for Japanese students, if they have sufficient qualifications and if there are available space and opportunities in the faculty or graduate school to which they apply.

The University Hokkaido itself provides no financial assistance for students. Therefore, it is preferable that everybody who want to enroll to the university, make sure to obtain scholarship financing from their own government, company sponsor or from the Monbukagakusho (MECSST) of the Japanese Government before submitting application form to Hokkaido University.

How to Apply

1) Applicants may take examinations offered by the Japanese diplomatic mission in their respective countries. Details of information may be obtained by writing directly to a Japanese diplomatic mission in the applicants' countries.

2) Applicants must pass an entrance examination given in February by the Hokkaido University. Details of entrance examination may be obtained by writing directly

to the Division for Student Exchange, Hokkaido University.

Contact: Division for Student Exchange, Hokkaido University

Kita 8, Nishi 8, Kita-ku, Sapporo 060-0808

Fig. 1 Unmanned helicopter for precision agriculture.

The helicopter has functions for remote gathering of field information regarding crop status and soil. The goal of this research project involves automatic operation for farm

Fig. 2 Rice grain elevator.

management.

Rice storage experiment under super-low-temperature condition using natural cold fresh air in winter in conducted on farm-scale facility. About 6000 tons of rough rice is stored in this type of grain elevator.

Fig. 3 Crop row following system for accurate weeding machine.

The CCD camera mounted on the weeding machine detects the crop row locations. The computer controls the weeding machine along the crop row using a hydraulic system.

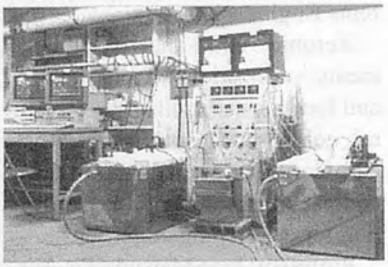

Fig. 4 Composting apparatus for organic waste in the laboratory.

Organic waste is digested before application in the field because organic waste decomposts rapidly in the field and the crops will be damaged. The objective of this work is to develop a proper procedure to reduce ammonia emission and to compost excellent organic waste. ■■

Research Activities on Agricultural Machinery at the University of the Ryukyus

by
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Introduction

The University and Faculty

The University of the Ryukyus (UR) is located in the southernmost part of Japan and in subtropical environment as shown in **Fig. 1**, which is only one National University in Okinawa Prefecture. The University was found in 1950 after the World War II at Shuri in Naha City. Now, the campus (**Fig. 2**) is in Nishihara-cho in the suburbs of Naha. When the administrative power of Okinawa returned to Japan from USA, the organization became to a National University. The University consists of six faculties; Agriculture, Engineering, Science, Law and Literature, Education and Medical Science.

Fig. 1 Location of Okinawa.

Fig. 2 Department of agrilulture building.

The Faculty of Agriculture provides education and research on bioresources of tropical and subtropical conditions. The distinctive advantage is to learn how tropical agriculture differs from temperate or non-tropical conditions in Japan. Research activities are inevitable for the progress of agriculture and agro-based industries such as a sugar mill. It is a goal for the Faculty to educate students who can work for the welfare of the local and international communities. There are three departments in the university: Bioproduction, Environmental Sciences and Technology and Bioscience and Biotechnology.

Considering fast changes and the radical innovations in science and technology and the dynamic changes in social and economical structures it is fundamental that reorganization of academic and research systems be undertaken which UR carried out in April 1991. Inevitably, the curriculum of special course for agriculture was also changed. Students learn the basic subjects during the first two years. As they identify their special interests, they select their major fields of study for the last two years.

The general education system in the country has reformed according to the new Standard of University Establishment issued by the Ministry of Education. New curricula were been introduced from April 1994. The faculty of General Education was repealed and the fundamental reorganization of the education system was carried out in April 1998. The Faculty reexamined the curricula according to the improvement of education system in1994, and the requisite of graduation was changed and reinstituted.

Department of Bioproduction

The main purpose of the Department is to impart to students education and research to produce useful bioresources by utilizing the climatic conditions of the tropics and subtropics. The Department teaches crop and animal production technology, information technology, management and distribution relating to the biological, scientific and engineering, social and economical fields which cover the wide area on the production of bioresources. The Department consists of five chairs: Tropical Crop Science, Plant and Animal Breeding, Animal Science, Production Systems Engineering and Agricultural and Forest Economics. For graduate students, they are provided with advanced education and research on the production of crops, animals and trees under a rich natural environment, using agricultural machinery and facility. Agricultural and forest economics are also offered.

Department of Environmental Sciences and Technology

This department provides lectures, practicum and laboratory exercises on water, soil, trees and animals to keep and sustain sufficient productivity consisting of four chairs: Water Use and Hydraulic Structure Engineering, Soil Science and Land Conservation, Forest Science and Subtropical Zoology. The former two chairs deal mainly with inanimate issues to improve potential productivity of farmlands and to create comfortable living and beautiful rural environment. The latter two chairs deal with wild plants, wild animals, livestock, sustainable management for trees and plants, and rational utilization of limited resources in small islands in the subtropics.

Department of Bioscience and Biotechnology

The aim of the department is to elucidate on the functions and structures of the compositions of organism by the biochemical, physicochemical and biotechnological methods, and to investigate the utilization of living bodies, development of biological functions, development and improvement of food resources, and effective utilization of biological products. The department consists of three chairs; Biotechnology and Applied Biochemistry, Applied Bioresource Science.

Production Systems Engineering

The chair of the Production Systems Engineering consists of two fields; Agricultural machinery and post-harvest and transport technologies. The staff members are two professors, two associate professors and one assistant. The major fields are: agricultural machinery, systems engineering and information technology, post-harvest technology, transport engineering and food process engineering. The chair offers education and research to achieve high efficiency and high quality in bioproduction by scientific and engineering methods such as mechanical engineering, systems engineering and information technology from the stage of field production to distribution of products. The major subjects are: Introduction to Systems Engineering in Bioproduction, Agricultural Process Engineering, Farm Machineries, Postharvest Technology of Horticultural Crops, Air conditioning in Bioproduction, Systems Engineering in Agriculture, Agricultural Energy Engineering, Physical Properties of Biological Materials and Information and Control Engineering.

Research Activities in Agricultural Machinery

As mentioned earlier, the University is located in the sub-tropic zone, wherein research activities in agricultural machinery differ from those in the mainland. The climate is sub-tropical and soil types are heavy clay. Severe drought takes place in summer due to uneven distribution of rainfall and shortage of water resources. In addition, several typhoons attack the Ryukyus. Thus, the climatic condition is not ideal for agriculture. Okinawa consists of many small islands, so the area of agricultural land is limited. Sugarcane, tobacco, vegetables, flowers and tropical fruits are cultivated. Almost much of the agricultural land is upland field and paddy fields are very few. Mechanization of agriculture in Okinawa is rather behind because of the special conditions in climate, soil types, crops and land use system which affect research activities.

The main subjects of research on agricultural machinery in the University are:

(1) Improvement of the traveling performances of agricultural machinery
(2) Mechanization of sugarcane cultivation
(3) Optimum mechanized production systems
(4) Development of information system and IT applications
(5) Precision agriculture in a small island
(6) Development of special machines for Okinawan agriculture
(7) Systems engineering for environmental preservation

Some of these are briefly presented as follows:

Improvement of the Travel Performances of Agricultural Machinery

Practical Studies on Improving the Traveling Performances

(1) <u>Simple judgment of trafficability for large-size farm machineries after a rainfall</u>

The dead weight of a sugarcane harvester ranges from 5 to 13 tons. Hence, soil compaction develops which is regarded as one of the most undesirable factors for crop growing and soil conservation. In addition, the harvest season of sugarcane, January to March, is rather rainy so that the harvester often stops when it rains or suffer remarkable sinkage. To judge whether the machine can operate or not is a very important problem for machine operation and farm management- which is classified as a problem on trafficability. It is important to know how many days the machine is able to operate for optimum scheduling. A statistical method called "discriminant analysis" was employed to solve it. Water content was the most dominant factor governing trafficability. Therefore, differences in soil hardness, water content and dry density were compared with the critical and the normal running conditions of a harvester. Soil is softened near the critical running condition with high water content. Inversely, it becomes hard and the penetration resistance is increased in normal travel. It was distinguished at high proportion with positive discriminant rate of 97.55%, when water content, dry density and penetration resistance were selected as parameters. Though it lowered on the positive rate, when the model was not limited to the size of harvester, the discriminant was possible. The rainfall of the day, the previous day and two days before were useful parameters as the discriminant was obtained.

(2) Adhesion and sticking properties of heavy clay

Soil sticking brings serious troubles such as energy loss, reduction of capacity and efficiency, and low accuracy to the operation of farm machines. To get superior performance of the machines, it is necessary to make clear the mechanism of sticking and to develop the methods to prevent it. The problems and form of various kind of sticking were summarized. In addition, adhesion and the process of sticking were discussed by referring some experimental results. It is suggested that in order for many researchers to be interested in this problem, the key point is to develop preventing technology against sticking.

Basic Studies on Travel Performances Using the Soil Bin Tests

(1) A precise prediction of travel performance

Drawbar pull, torque and travel resistance can be easily estimated if we know the ground contact stresses applied on a rolling wheel. Therefore, the main subject is to predict precisely the stresses to improve the travel performance. An empirical equation called "Bekker's method" which describes a relationship between the ground contact pressure and the settlement of a plate has been used. Some derivative methods have been widely employed for mechanical analyses of the travel performance. Many researchers, for example, J. Y. Wong, calculated the distribution of normal stress by this method, then the tangential stress was calculated. The drawbar pull and the torque were estimated by integrating these stresses. There are many problems or limitations in these methods as pointed out by some researchers. Sinkage behavior is the most important factor in such method. Sinkage of the traveling wheel varies continuously so that the contact width or the region changes. Because of the change in stress distribution, such variation causes the sequential changes of drawbar pull and torque. In addition, sinkage behaviors differ by slip of the wheel. The relationships were analyzed by the use of experimental results employing a model rigid wheel (**Fig. 3**). Then, a precise prediction system of travel performance for a rigid wheel was developed in this study by employing modified equations for estimating the distribution of ground contact stresses taking into consideration the effect of slippage. Prediction of drawbar pull or torque is achieved by a series of calculations, that is, sinkage by an empirical method, distribution of normal stress by a modified equation based on Wong's method, distribution of tangential stress by Janosi's method, and finally, drawbar pull and torque are calculated by integrating these stresses. The predicted results adequately satisfy experimental results except at low slippage. The system has enough applicability in the practical sense.

(2) Soil deformation under a traveling wheel

A large number of researches on soil compaction has been reported. However, the accurate movement of a soil particle has not been sufficiently elucidated on. A model wheel was traveled and the soil deformation was analyzed using the on-line measurement system as shown in **Fig. 3**. Soil particles in the neighborhood of the wheel was displaced as drawing a circular trajectory with access and passage of the wheel (**Fig. 4**). A similar tendency of the trajectory appeared in the various levels of void ratio. Though soil particle behaved similarly in the deep layer, the size of trajectory circle decreased with an increase of depth.

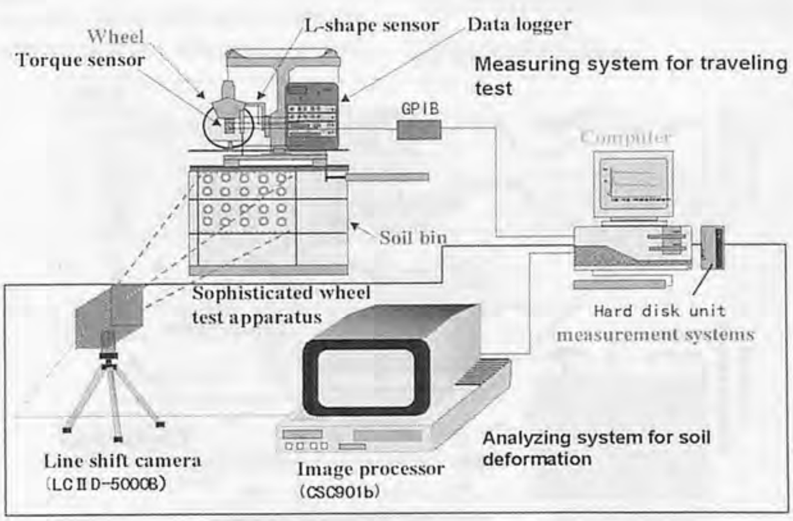


Fig. 3 Experimental apparatus of traveling test.

(3) Soil deformation in repeated travels of a wheel

Soil compaction is related mainly to soil deformation due to the stress applied through the wheel or the track. Although many researches on it have been carried out, almost of them, however, are limited to the research on single pass travel. Soil is repeatedly compacted in the actual machine operation so that the problem has not been sufficiently clarified. The hardening process and soil deformation are analyzed by the repeated travel tests of a wheel.

Mechanization of Sugarcane Cultivation

Development of a Small Green Cane Chopper Harvester

A small green cane chopper harvester was developed, distinctive feature of which is the ability of the upper part of the machine to pivot around the crawler trawler track under-carriage to allow two-way working in small fields without damage caused by turning the conventional crawler equipment in the field. After three years of trials (1982-84), the capacity of the harvester was still relatively low in green cane compared with Australian combines in burnt cane. Cleaning reached a satisfactory level considering the relatively low engine power (130 HP). Some problems still remain to be solved before the unit can be counted as commercial. The mobility of the tracks and the cleaning performance had reached the target levels which were the main test items in this project. It was confirmed that the top-turning mechanism was effective. There were, however, many problems to be solved, especially improving the cleaning performance and cutting height control. Basic research is necessary to solve these problems.

Evaluation of Harvesting System

In order to select a suitable harvest system different systems (**Fig. 5**) available have been evaluated, and the differences between unburnt harvesting and burnt harvesting of canes have received particular attention. Data related to field costs of green cane harvesting (performance, cane loss, quality of cane billets, soil compaction) over a three-year period are presented. Green cane harvesters were found to have about two-thirds of the capacity of burnt cane harvesters. There is a clear difference in quality of billets after harvesting unburnt and burnt cane. Though soil compaction immediately after harvest is similar, there is a considerable mulching effect with unburnt harvesting. Successful development of an unburnt mechanical harvesting system can be assured although some problems do remain. Tests have been carried out over three years to adjust and improve the unburnt harvesting system. Green cane harvesting proceeds at roughly 2/3 of the rate when harvesting burnt cane. The cane loss, damage to billets, trash ratio, and deterioration should be analyzed, because these factors relate not only to the performance of the harvesters, but also to the economical assessment of green harvesting system. Tests are being continued to obtain more detailed information.

Sugar Loss due to the Mechanical Harvesting

Cane sugar is produced in three stages: field production, manufacturing and harvesting stage which connects the first two stages. More attention should be paid to establishing a more effective total sugar production system. Traditionally mill yield is the main subject of our interest relating to sugar loss. In other words, the loss in the milling stage is regarded as the sugar loss itself and a great deal of effort has been concentrated on reducing it. On the other hand, there can be much sugar lost in the other two stages, although this is often not recognized. This sugar loss has many elements; for example, the reduction of cane yield due to disease, insects, drought, lack of fertilizer and so on should be included in this sugar loss. Quality control right through from planting to milling is necessary to establish a properly integrated sugar production system. Mechanical harvesting brings about a great advantage to a

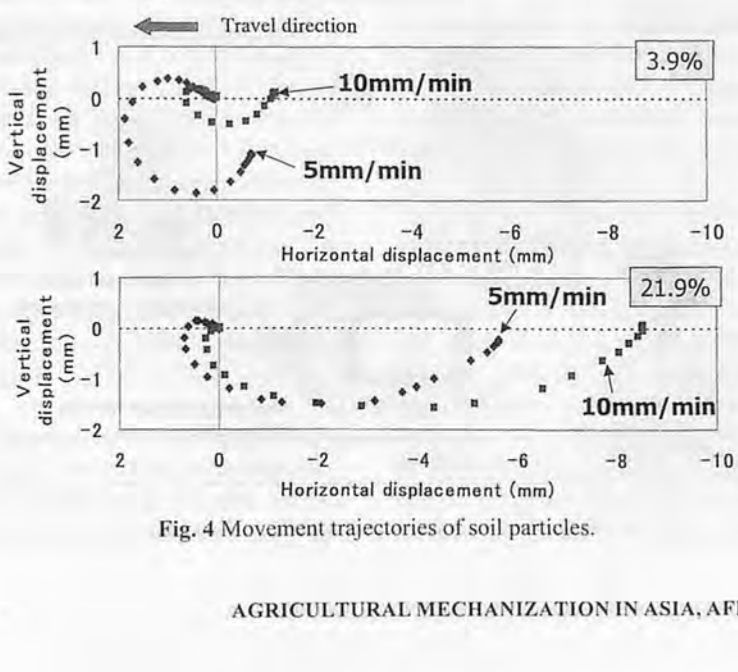


Fig. 4 Movement trajectories of soil particles.

Fig. 5 An example of mechanical harvesting.

cane grower. Time saving and cost reduction are important considerations. These effects are obtained in suitable conditions for a mechanized production system, but the mechanical harvesting becomes harmful whenever it is applied under unsuitable conditions. Considerable cane loss can occur during cutting and transportation. Sugar loss also occurs on subsequent deterioration of cane due to mechanical harvesting. Trash included in the cane absorbs juice in the mill processing, giving rise to mechanical harvesting and which has been the subject of this study. Loss in a sugar production system was categorized into three elements: the field stage, harvesting stage and milling stage. A mathematical expression to define sugar loss was attempted by introducing the concept of an expected, or standard, yield of sugar. Attention was focused on harvest losses and deterioration. Harvest losses of 10-15% were frequent with green cane harvesting. Billet damage was also examined, and the influence of various factors in deterioration during storage. Deterioration was affected by damage, rainfall and the location in the stockpile.

IT Applications in Agriculture

Information System to Assist the Precision Farming of Sugarcane Production

In Japan, sugarcane is grown at Nansei Arcs located in the southwestern area which consists of Okinawa Prefecture and a part of Kagoshima Prefecture. Sugarcane is a major crop in Okinawa with 50% of farmland and 70% of farmers engaged in its production. The yield and income in Okinawa reach about a million tons and 20 billion yen, respectively. Recently some factors such as aging of farmers and a relative decrease in income have resulted in a serious reduction in output. However, sugarcane is still valued as an indispensable crop in Okinawa because of its superior qualities such as its economical effect on rural society, especially small islands, the high productivity of its bio-mass, toughness to typhoon and drought and preservation of environment. In addition, the price of sugarcane has turned to evaluate from the weight to the quality, i.e., content of cane sugar since 1994/95. Farmer's income depends on both weight and quality. The price within the range in 13.1-14.3% sugar content is set at ¥20,190/ton. A change of 0.1% increase/decrease by 130 yen (about one US dollar) in the outside of the range so farmers are compelled to improve their farming.

To overcome such severe situations, new production systems should be established to realize not only high-yield, high-quality and high-efficiency, but also low input and sustainable agriculture. The systems execute precise control for cultivation and management according to the conditions of the farmlands and crops by systematically using various kinds of information. In this study, an information system in order to carry out the production assistance was constructed. For the success of the information system, effective data collection with low cost is important. The quality-oriented purchase system was utilized as the data collecting system. Therefore, numerous volumes of quality data can be automatically obtained by the system as shown in **Fig. 6**.

In this study, an information system for the production assistance and precision farming of sugar cane was constructed by using numerous volumes of quality data obtained by the quality-oriented purchase system. Minami-Daito Island was selected as a model area to found such information system. Basic concept, constitution and application of the system were discussed by focusing on the island. Distribution characteristics of the sugar content were checked, and the effects of cropping type and variety were analyzed, and some distinct properties were made clear. It was clarified that sugar content changed continuously during the harvest season, which increased in the latter half and could be described by a parabolic curve. Characteristics of the production system were investigated by the analysis of quality information, and distributions of data relating to the households and fields were evaluated as fundamental information for precision farming. Case studies about four farmers demonstrated that the system was applicable to precision farming.

NIR Application

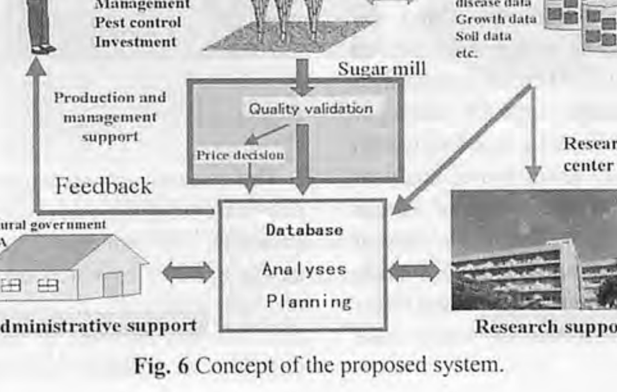


Fig. 6 Concept of the proposed system.

The purpose of this study was to analyze the components of sugar cane juice in order to improve the cultivation practices and to achieve high yield, high quality and low input of fertilizer (**Fig. 7**). Whether the Near Infra-Red analyzer could be employed to realize it was mainly focused. Chemical analyses of the juice components were carried out by a ICP, an ionic chromatography and liquid chromatography in order to make calibration equations and to check accuracy. In total, 135 samples of cane juice gathered from Minami-Daito Island and University Experimental Farm were supplied. It was statistically confirmed that the components, sucrose, glucose, P, K, Mg, S, Si, fructose, Na were analyzed with a certain level of accuracy.

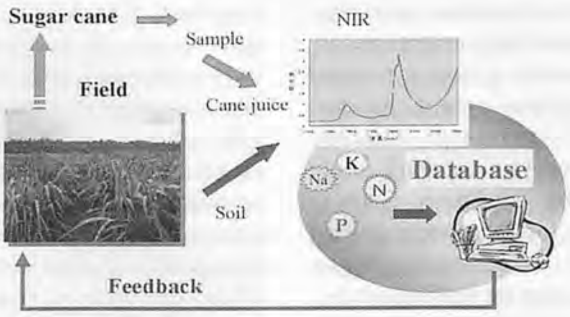


Fig. 7 Extending the function of NIR.

Application of Geographic Information System (GIS)

A model information system equipped such data collecting system was developed in Minami-Daito Island. The availability of the system to improve the cultivation and management of individual farms was demonstrated by these case studies. GIS was employed to execute spatial analysis for the achievement of the purpose of the system. Basic concept, constitution and application of the system were discussed by focusing on the production system of the island. Distributions of the sugar content were checked, and the effects of cropping type and variety were analyzed. Some distinct properties were clarified. Sugar content changed continuously during the harvest season, which increased in the latter half and could be described by a parabolic curve. It was confirmed that the GIS was a powerful tool, a good viewer and an analyzer of the spatial distribution of data as shown in **Fig. 8**. The availability of the system to improve the cultivation and management of individual farms was demonstrated by some case studies.

Application of Genetic Algorithm (GA) to Scheduling

The application of Genetic Algorithm (GA) to improve the harvesting stage of sugarcane were examined by using the unit yield model and the sugar content model taking into consideration the characteristics of cropping type. In this study, the method to optimize the harvesting schedule and its starting date was discussed. At first, it was shown that the problems were regarded as a combinational optimizing problem, then the formulation of GA was carried out according to some basic assumptions and the analyzing method was developed. Some simulations were carried out in order to optimize the harvesting sequence and starting date. The GA solution was checked whether or not the optimum one by comparison with some models derived by the empirical considerations and actual conditions of harvesting. The GA seemed to be effective in solving these problems because of the rapid convergence.

Concluding Remarks

The research activities mentioned above are related closely to the local problems encountered the Okinawan agriculture which are greatly different from those in mainland Japan. The environment of the small islands is so sensitive to the human

Fig. 8 Distributions of sugar content by GIS.

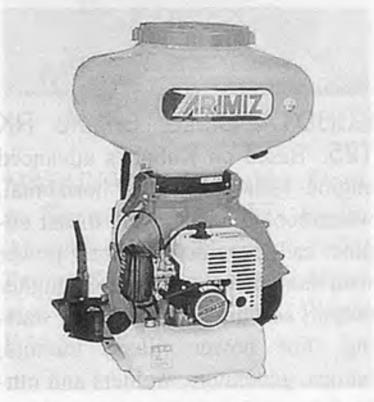
activity that we should develop the technologies for sustainable agriculture. These activities are limited by the shortage of manpower, budget, facilities, information and storage of knowledge, hence we have to put great effort to overcome the handicap. At the present time, we are trying to establish networking with universities, agricultural Experimental Station of Okinawa Prefecture, association of sugar mills, Agricultural Cooperative (JA) and private companies. Two big projects, to develop an information system assisting the production and management using new technology and to establish the bio-ecosystem preventing global warming are in progress. ■■

Main Production of Agricultural Machinery Manufactures in Japan

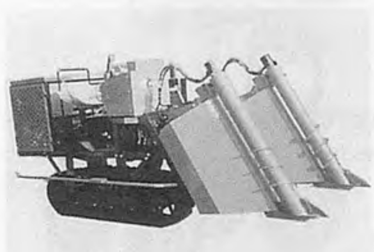
by
Shin-Norinsha Co., Ltd.
7,2-chome, Kanda Nishikicho, Chiyoda-ku, Tokyo, 101-0054 Japan

Introduced here are the main products of agricultural machinery manufactures in Japan with a number of photographs.

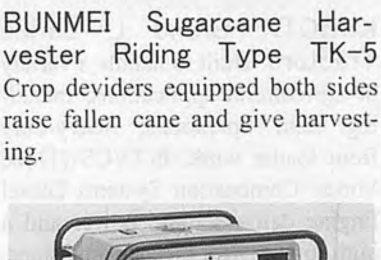
The products are developed and improved for both foreign and domestic markers. For further information please refer to the manufactures contained in the directory.



ARIMITSU Knapsack Power Duster Model SG-7030. Light-weight, compact design, but ensuring to produce bigger air volume due to high performance turbo-fan be driven by the powerful 60CC gasoline engine. Chemical tank can be quickly mounted or detached by menas of the lock or release lever. Size (L × W × H): 360 × 520 × 740mm, weight: 10.5kg, Max. output:3.7ps/7500rpm, Chemical tank capacity:28l, AIr volume: 140m^3/min, Max. static pressure: 990 mm AQ.



BUNMEI Sugarcane Harvester Riding Type TK-5 Crop deviders equipped both sides raise fallen cane and give harvesting.



DAISHIN Portable Generator SGB4000HX. Brushless generator; Non-fuse breaker; Quiet operation; AC volage: (50Hz); (60Hz) Max.Output: (50Hz)3.6kVA (60Hz)4.5kVA.Engine: Air-cooled, 4-cycle,gasoline 5.2PS, 6.2HP;Dry weight 65kg.

CHIKUMA Corn Sheller Type3. Removes kernels from corn-cobs by a short time. Capacity: 750-1, 125kg/h, Power r'd: 1-2 PS, R.P.M.: 300-500, Size in mm: 1,015H × 575W × 1,010L, Weight: Net 90kg Gross 130kg, Shipping mess.: 18cft.

ISEKI TF325 Tractor. Mounted with powerful and economical 25PS water cooled diesel engine. The tractor offers wide range of travelling speeds from approximately 2 km/h to 22 km/h, which offers broad operating application and safe road travelling.

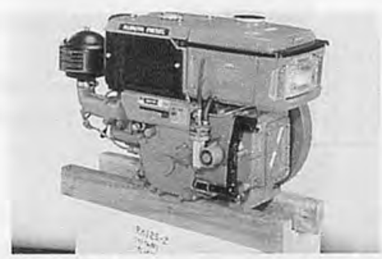
ISEKI SF300 Mower. The 28 hp diesel engine gives you the power you need to deal with all your mowing tasks quickly, while its efficient use of fuel makes it economical as well. Cutting width: 1524/1830 mm, Cutting height: 30-120mm.

ISEKI Multi-Purpose Tiller KV700D. Four-cycle/direct injection/6PS engine allows heavy-duty operation at low speeds with ample power in reserve. Light, Compact, Easy to use and high performance.

KIORITZ Battery-powered U.L.V.Sprayer(Shoulder type)ESD-5. A compact and lightweight battery-powered U.L.V. Sprayer providing easy portability combined with high performance. It is designed for use in environmental hygiene control such as malaria prevention, etc. in addition to general-purpose applications. Operates on six 1.5V batteries. A rechargeable battery pack can also be used.

KUBOTA Grand L Series Tractors. Built to handle a variety of agricultural applications, including field operations, heavy-duty front loader work. E-TVCS (Three Vortex Combustion System) Diesel Engine delivers more power and a high torque with cleaner emissions. In the GST (Glide Shift Transmission) models, the New GST features clutchless operation "shift-on-the-go" with faster response time and less power loss.

KUBOTA Combine Harvester SKY ROAD PRO 481. Easy to operate, micro-computerized 4-line combine harvester that cuts down on time as well as crops. Equipped with many helpful mechanisms and a reliable water-cooled diesel engine. Max. output: 48PS/27000 rpm.

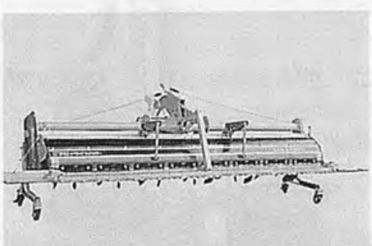


KUBOTA Diesel Engine RK 125. Based on Kubota's advanced engine technology, the horizontal, water-cooled and 4-cycle diesel engine can provide full-bore power with less fuel consumption, higher output, and quick and smooth starting. For power tillers, tractors, pumps, generators, welders and other farm and industrial used. Max. output: 12.5 HP/2400 rpm.

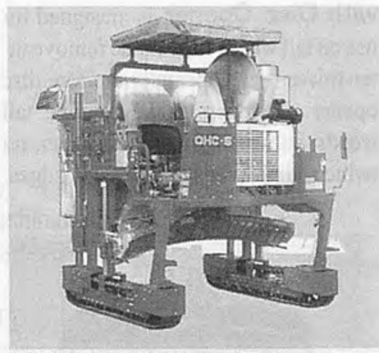
MAMETORA Vegetable Transplanter TP-4. This machine is available in both pot and soil block in seeding transplanting. Application: all vegetable nursery.

MAMETORA Power Cultivator SRV4F. Wide range use: cultivation to riding, Mounted with 7 PS engine.

MARUYAMA Portable Power Sprayers MSO55D. Engine: Air-cooled, 2-cycle, output 22.6cc, Pump: Suction capacity 5.1*l*/mm, max pressure 25 kg/cm^2, Weight: 8.5 kg.

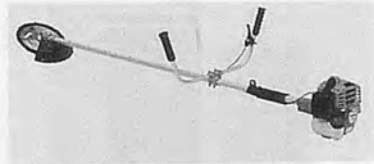


NIPRO Drive Harrow HR-2408B-3S for paddy field. Working width: 244 cm; Required tractor horsepower: 24-40HP.



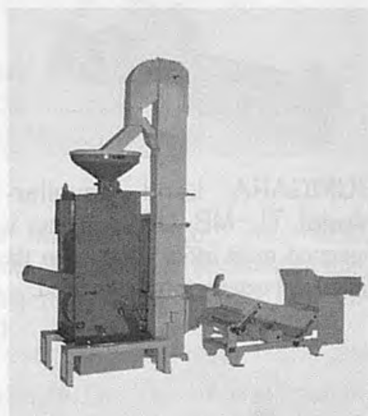
OCHIAI Riding Type Tea Picking Machine OHC-6. Full working width cutter bar. Stepless speed control. Water-cooled Diesel engine 29PS

OREC Power Cultivator AR700. Wide range use: Cultivation to riding. Mounted with 7 PS ~ 7.5PS engine.



ROBIN Brush Cutter Model BF2100(AU). 2 cylinder engine (20cc) makes the lightest model in the wolrd and comfortable (low noise and vibration). Rotational speed of blade 4000-6000rpm.

SASAKI Fertilizer Spreader BF-300. The lever type action controls the amount of application with high accuracy. Application width: 10-12m. Hopper capacity: 300*l*. Required tractor horsepower: 20-50PS.



SATAKE Mill Top. Compact Rice Milling Unit including paddy cleaner, Rubber roll husker and friction type rice milling machine. Input capacity: Approx. 650 kg/hr on long grain rice. Required power: 25 PS engine (standard).

SHIZUOKA's Single Kernel Moisture Tester CTR-800E for rough rice, brow rice, wheat and barley.

STAR Mini-Roll Baler MRB 0840. Automatic pick-up, rolling and ejection. One bale every 30 seconds, Handy bale size (50cm in diameter and 70cm long). Required tractor horsepower: 18-30 HP.

SUKIGARA Land Leveller-Model TL-MB/H3. A tractor is operated most effectively when the field has been uniformly levelled.

SUKIGARA Triple Row Ridger with Disc Opener is designed for use on tall weeds to be made remove inter-row-crops. Especially the fore disc opener of ridgers make remove tall weeds, so ridging operation easier, no twine round weeds to tines and ridges.

TANAKA 2-Cycle Engine Pure Fire is an environmentally kindly engine that cleared the secondary exhaust fumes control by the U.S. CARB. Both 26cc and 42 types are available. The engine just for the 21st century.

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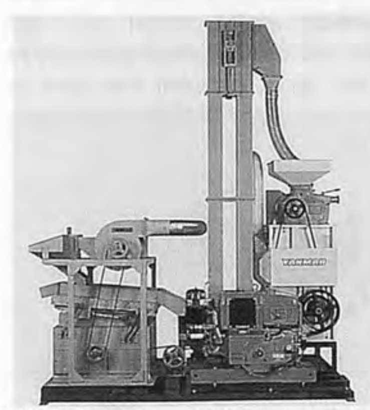
YANMAR Diesel Tractor F-ex Series. 5 models: 21ps, 28ps, 32ps, 37ps, 42ps. Compact, quiet and vibration-reduced diesel engines are mounted at the heart of these F-ex series tractors. Engine: vertical, 4-cycle, water-cooled. Transmission: gear shifting. F8 × R8 or F9 × R9 Drive system. 4-wheel drive.



YANMAR New Mill Mate YMS-650U. Cleaner/destoner + Huller & Polisher + Engine. Input cap: 800kg/h, Engine 23ps. This machine is a complete direct-through rice mill consisting of a hulling section, winnower and polishing section. ■■

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ABSTRACTS

The ABSTRACT pages is to introduce the abstracts of the article which cannot be published in whole contents owing to the limited publication space and so many contributions to AMA. The readers who wish to know the contents of the article more in detail are kindly requested to contact the authors.

004

Development and Performance Evaluation of Tractor-drawn Multi-crop Planter: **J.S. Deshpande**, Asstt. Professor, Agril. Engg. Research Centre, College of Agriculture, Pune. **P. A. Turbatmath**, Asso. Professor, Same. **S. V. Rane**, Asstt. Professor, Same. **M. B. Shingte**, Principal Investigator, Same.

Placement of seeds equidistantly provides enough opportunity for each plant to grow with high vigor at it provides adequate amount of sunlight, water and nutrients. About 7.15% more yield is obtained by adopting this technique. The Agricultural Engineering Research Center, College of Agriculture, Pune (MPKV) has developed a tractor-drawn planter which suits to variety of crops for planting at row spacings of 22.5, 30, 45, 60, 75 and 90 cm and maintains plant-to-plant distance by using suitable seed plates.

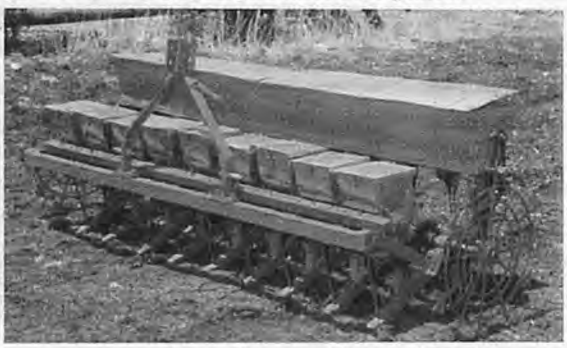

Fig. 1 Tractor-drawn multi-crop planter.

The machine was taken for demonstration and popularization in the adopted village Sarsod for sowing of raya, gram crops as ridger-seeder. It is capable of sowing 5-6 hectares per day depending on type of crop sown. There was 30-40% savings of irrigation water with its use as ridger-seeder. Several hundreds demonstrations were organized during last two years and about 12-15% higher yields were obtained by the farmers.

007

Design, Development and Field Evaluation of Tractor-drawn Multi-crop Ridge-furrow and Flat Bed Seeding Machine for Rainfed and Irrigated Conditions: **D. N. Sharma**, Professor, Farm Power and Machinery, Dept. of Farm Power and Machinery, College of Agriculture, Engineering and Technology, CCS HAU, Hisar-125004, INDIA. **D. P. Kataria**, Dean, Same. **V. P. Bahl**, Associate Professor, Same.

To meet the seeding requirements of different crops, a tractor-drawn, ridger-seeder was improved upon and a multi-purpose tractor-drawn seeding machine was developed. This machine can accomplish sowing of crops both on flat bed as seed-sum-fertilizer drill like wheat, barley and methi crops and ridger-seeder with slight modifications/adjustments.

It was field tested. T has three-point hitch, two bottom ridger-seeder which form the ridges and furrows with seeding either on ridges, sides of ridges or in the furrow openers for a use as see-cum-fertilizer drill on flat bed sowing.

026

Human Energy Count in Fodder Collection: **Bimla**, Research Associate, Farm Power and Machinery, Dept. of Farm Power and Machinery, College of Agriculture, Engineering and Technology, CCS HAU, Hisar-125004, INDIA. **Sudesh Gandhi**, Scientist, Same. **Mamta Gandhi**, Research Associate, Same. **Kusum Rana**, Asstt. Scientist, Same. **Rajendra Singh**, Statistician, Same.

To know the energy expenditure while collection of fodder. A ergonomic study was undertaken during the collection of fodder in order to determine the energy used. Twenty women participated in the collection of fodder. It was observed that an average women carried a weight of 43 kg in bundle of fodder. However, the average weight carried by a woman of 21-30 years of age was more (46.8 kg) than those of 31-40 years of age (40.8 kg). A woman traveled a distance of 3.73 km/day for collection and bringing fodder and spent 3 hours daily for the activity. Maximum time was spent on fodder cutting (122 min) followed by backward trip. Under bio-mechanical assessment postural analysis was done and it was observed that bending position was adopted for a maximum number of times while cutting fodder and bundling. The angle of deviation was maximum for the lumbar region, i.e., to the extent of 47 and 42.7 during fodder collection in women belonging to 21-30 years and 31-40 years of age respectively incidence of muscle-skeletal pain which was reported to be quire high for both lumbar and cervical regions. Sever pain was reported in the neck and lower extremities by the responders. It is recommended that necessary training need to be imported to rural women in reducing their drudgery. ■■

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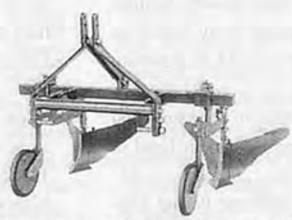

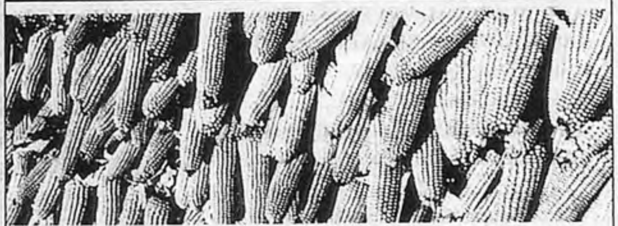

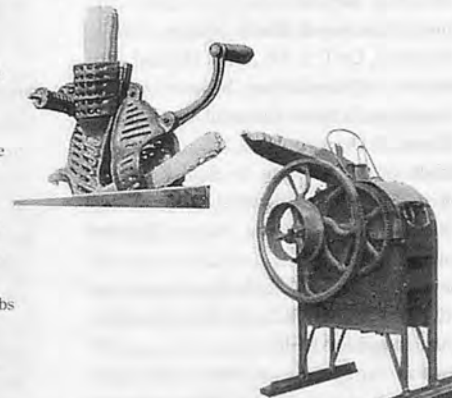


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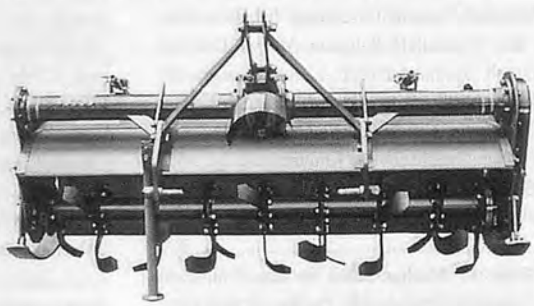

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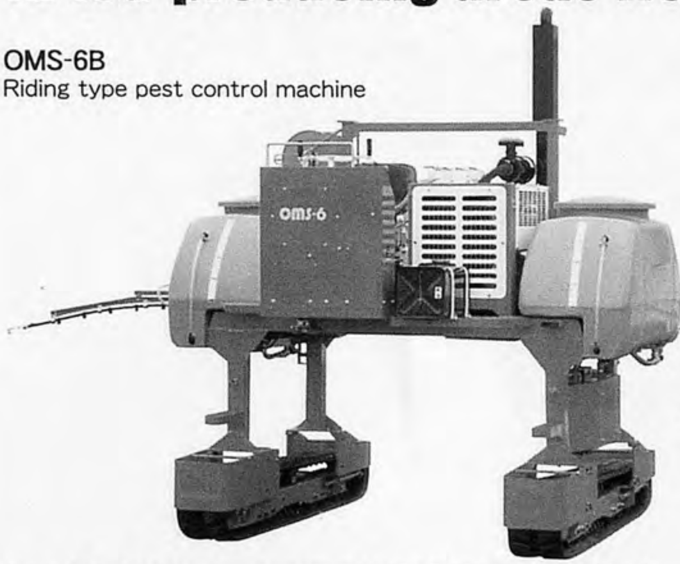

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